GENERAL ELECTRIC Review

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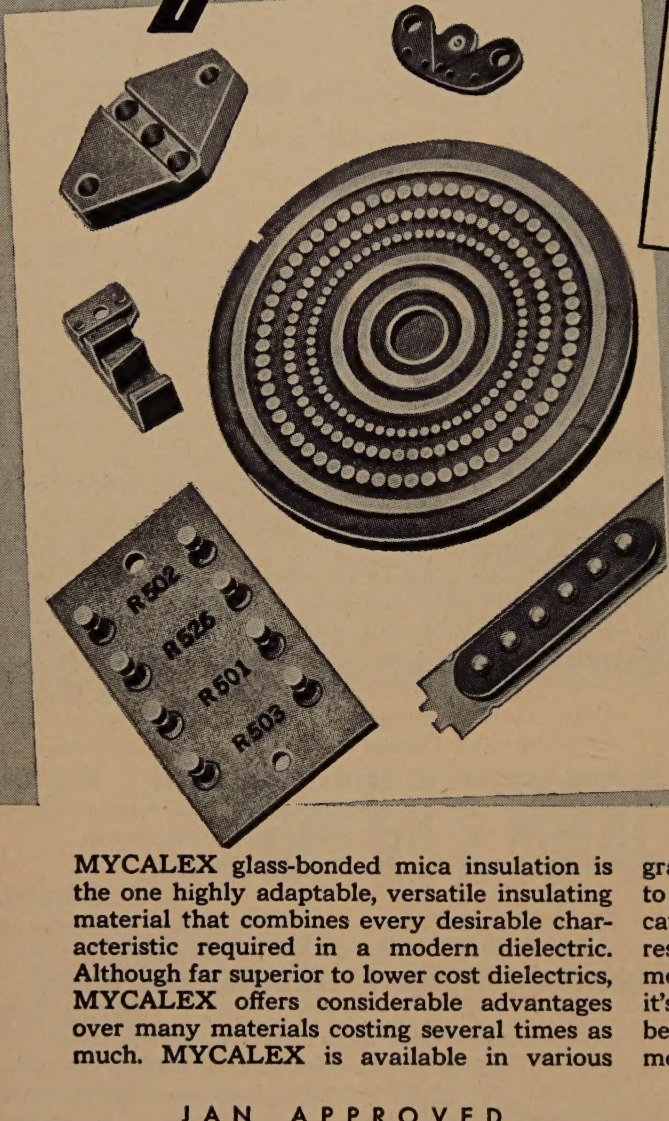

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LOSS FACTOR, 1 MC	0.013	0.014	0.084
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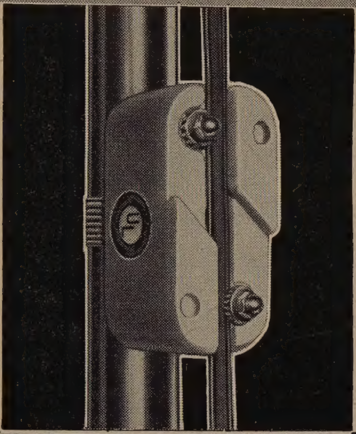

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- Protects TV Set and Home Against Lightning Damage.
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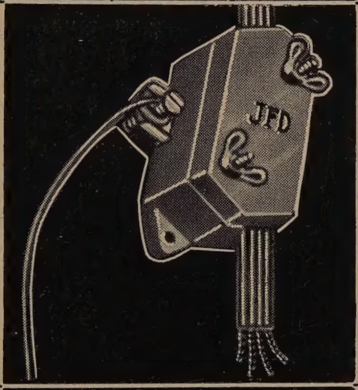

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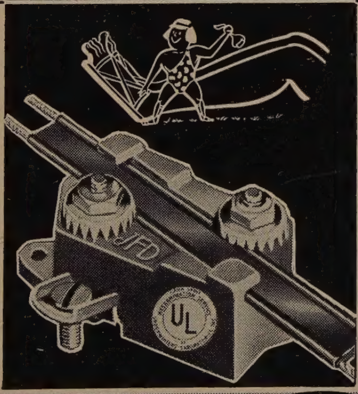

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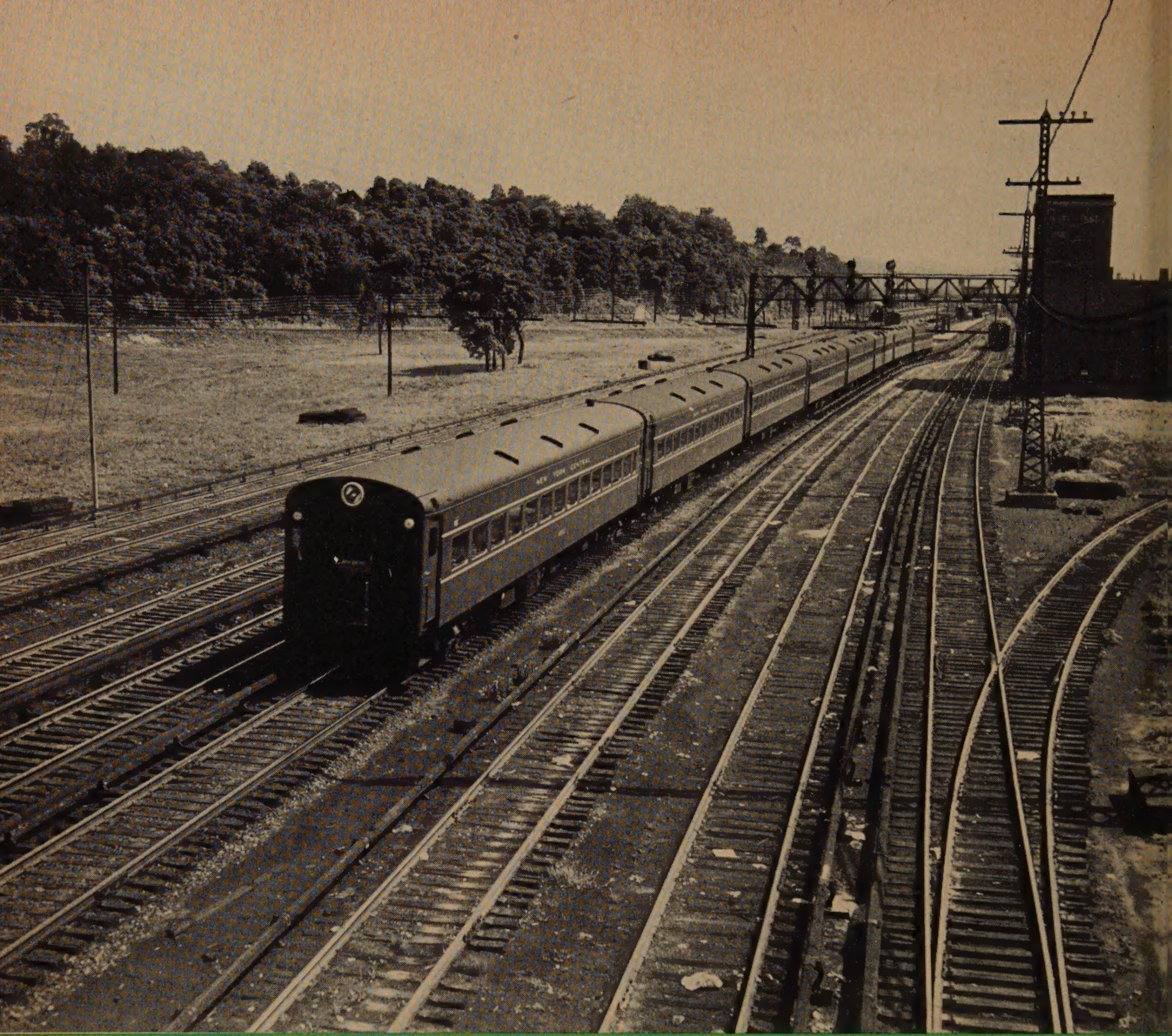

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by the New York Central Railroad, carry thousands of commuters daily to and fro
Grand Central Terminal, New York. Operating from a 600-volt d-c third-rail syste
these trains furnish comfortable and speedy transportation, summer and winte

(See p. 6

GENERAL ELECTRIC Review
OCTOBER
1951

LEADERSHIP

ADER is one who does not wait to be led. The ientist is a leader as he has brought forth new lge of the universe in which we live. The engi- a leader as he has used this knowledge to it into products for the people to have and to the things we have in the fullness of the stand- ving in our great country have felt the head and d and the heart of the scientist and the engineer. t them none of the things that we have would me into existence. With them we have all that e, and they are the open sesame for all of the yet to come.

ever you are you see the work of the engineer. of our great dams and reclamation projects, and harbors, buildings, and roads, stands the gineer. In all of our automobiles, railroad trains, es, and in all of the machinery in our factories, on ms, or in our oil fields, stands the mechanical r. In all of our mine products and metallurgy the mining and metallurgical engineer. In all of at process industries, foods, chemicals, petro- and in all of our factory chemical processes the chemical engineer. And in all of our electric and machinery everywhere, in all of our home ice electric appliances, in our lighting, in our ne and telegraph and radio and television, he electrical engineer. And in the new knowledge universe, brought to the engineer, stands the t. Everywhere around us the handiwork of the t and the engineer abounds.

ay be a new thought to many people that the r and scientist are *leaders* in their daily work. s true, nevertheless, and I say it again. For those ll question this thought just look about you, u can take it for a certainty that behind any hings you see there is a story of accomplishment, that began with the leadership of the scientist e engineer. And if they had not been leaders ould not have come into being the things which e.

y there is a shortage of engineers and of scien- here is a shortage because the problems of the uiring technical solution have multiplied beyond vious thought. This has been brought about because of the threat from without to our free institutions. We are rising to defend them. Every minute of the day and night the news is full of this; our elected leaders are in the thick of it; no one of us can escape it. It is now a part of every life; it is universal with us. It must not depress us; it must give us the strength to go forward into essential accomplishment.

And in the beginning of all of the essential accomplishments of the production of tanks, guns, planes, and other defense requirements, together with all the civilian needs, stand the scientist and the engineer. Their leadership is being utilized every moment. And as the requirements are ever increasing so is the need for engineers and scientists ever increasing. It may be difficult for the people to see this, but it is a fact. It seems to be hard for some of our elected representatives to see this, but it is still a fact.

It was just a few years ago that there was thought to be a surplus of engineers, and such an influential arm of the government as the Department of Labor spread a statement of this through the press. That surplus never came. Today the alarm—a genuine one this time—is entirely different; there is a shortage of engineers and also of scientists. It follows, therefore, that they should be continued in their places. Students of engineering and science should be permitted to complete their courses and take their places to bring their type of leadership to bear upon the problems of the day which have to be solved. This is not class favoritism; it is just good common sense.

The whole point is that the engineers have through the years been one of the great forces in achieving the tremendous productivity of our country. Heretofore there has been too little recognition of that fact and they must be brought into the foreground of recognition to their rightful place. Through the years as they have contributed their part in bringing us the things we have, they have never beaten the tom-toms for themselves. They could well be called the unseen men in the productivity leadership of our country.

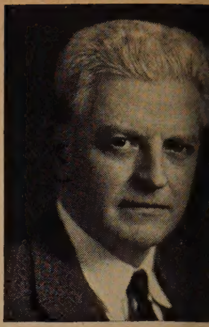
But it is different now and there must be definite recognition of the engineer and the scientist if our country is to advance. All the facts and figures point this out.

Everett S. Lee

WHAT MAKES THE ECONOMY TICK?

The influence of basic factors responsible for the high productivity of the American economy. Recent trends, and the vital stimulus needed to maintain its rapid increase

By SUMNER H. SLICHTER
Lamont University Professor, Harvard University



Sumner H. Slich

THE American economy is the most productive in the world. With less than 7 percent of the world's population, the United States produces almost 40 percent of the world's goods. This means that the average worker in the United States is about nine times as productive as the average worker in other countries. In some of the western European countries, output per worker is from one-half to two-thirds as much as in the United States; in Canada, it is almost as much as in the United States.

Productivity of the American Economy

What is the explanation for the extraordinary productivity of the American economy? The *immediate* explanation is the use of large amounts of power-using equipment per worker. There is a close relationship between the proportion of the world's goods produced by the American economy and the proportion of the world's power consumed by the American economy. Not only does the United States produce about two-fifths of the world's goods, but it produces about 38 percent of the energy turned out in 30 countries containing about four-fifths of the population of the earth. The use of energy per person engaged in mining and manufacturing in the United States is about 89 percent higher than in Britain, 30 percent higher than in Canada, and more than three times as large as in Germany and France.

The influence of power-driven equipment upon production is shown also by the close relationship between the growth of output per worker and the growth in the use of power. Between 1900 and 1940, horsepower-hours of energy from minerals, fuels, water power, and work animals increased about three times as fast as the use of human energy, and output per man-hour increased about 2.7 fold.⁽¹⁾⁽²⁾

Industrial Research

The growing use of power and of power-using equipment is made possible only by changes in methods and the development of new materials. To increase greatly the use of power per worker in local transportation, for example, it was necessary to replace the horse with the automobile or truck. The development of new methods and new materials is brought about in the main by industrial research, which has been expanding rapidly. Expenditures on industrial research were nine tim large in 1940 as in 1920, and they are twice as large as they were in 1940. The number of chemists, assa and metallurgists has increased from less than 90 1900 to 60,000 in 1940; and the number of tech engineers from about 43,000 in 1900 to 278,00 1940. In 1920, there were about 300 laboratories 9000 employees engaged in industrial research. By there were 2200 laboratories with more than 70 employees.

The change in methods shows itself in the chang the kind of power used by industry. Between 1900 1940, for example, the horsepower-hours of energy work animals dropped over one-half, but energy waterpower increased more than 18-fold; from 90 percent; from petroleum, over 20-fold; and natural gas, about 11-fold.

Basic Influences

The great productivity of the American eco cannot be satisfactorily explained merely as a res the use of large amounts of power and machinery. explanation, through valid, is also superficial. It not tell us *why* the United States uses far more p and machinery per worker than other countries. countries also have the opportunity to use powe machinery. The discoveries of modern technolog published in books and journals that are availab everyone. Why does America use so much more p and power-driven machinery than other cou and spend so much more on industrial research? are the questions that must be answered in expla the great productivity of America's industry.

Seven principal conditions explain this high ductivity. Although some of these conditions a longer in existence, or have considerably diminis importance, their effects still last. Other ones of conditions became important only after industr came well established here. The seven condition

(1). The individualistic and enterprising cha of the immigrants to this country;

(2). The newness of the country and the quent weakness of traditions;

(3). The lack of class organization and st cation;

(4). The scarcity of labor and capital in re to natural resources in the early days of the cou

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(1) Dewhurst and Associates: *America's Needs and Resources*, p. 787, Twentieth Century Fund, New York.

(2) Committee for Economic Development: *How to Raise Real Wages*, p. 31, New York.

5). The suitability of the land in most parts of country for small owner-conducted farming and unsuitability for the development of large-scale ning;

6). The large population in a free-trade area; and

7). The rapid growth of the country.

individualistic and enterprising character of the grants to this country. A large proportion of the immigrants to America sought religious or politi- erty. In later years, economic opportunity be- more important. The long, expensive, and arduous ey discouraged the week and the lazy, whereas ig rewards to be gained attracted the hardy and ourageous. Thus the immigrants to the United s tended to be more than ordinarily freedom- g, ambitious, and enterprising, and the country oped strong traditions of self-reliance and in- ual initiative. Although the population of the d States is now nearly all native-born, from 1880 20 about 13 percent of the population was foreign- and many more were children of foreign-born ts. The steady influx of immigrants tended to alive the traditions of individual initiative and prise.

newness of the country, and the consequent weakness litions. An important reason for the high produc- of American industry and the rapid technological ess here has been the receptivity of the country to ological change—the willingness of American prises to experiment with new methods and to old equipment. This is in contrast to countries rope where the environment is less friendly to e, particularly to technological change. American -unionists and businessmen who have visited pe recently have all been struck with the adherence to conventional methods of production and to latively weak interest in the possibilities of im- ng production methods.

principal reason for this difference between the d States and Europe is the newness of the country he lack of traditions here. Industry is not the area of human activity in which the American nment is much more friendly to innovation than uropean. Another area is religion. During the last ry and a half, many new religions, or religious have started in the United States. Nothing com- le has happened in Europe.

yet, there are some spheres of activity in which untries of Western Europe seem more receptive ange than does the United States; for example, countries of Western Europe appear to be less vative in their thinking about political institu- than is the United States. Britain, Germany, and of the Scandinavian countries have been more than the United States to consider more or less changes in economic and political institutions. s field, the more limited economic opportunities rope have fostered receptivity to radical political ideas, whereas the abundance of opportunity in the United States has encouraged adherence to the individualistic political philosophies of the nineteenth century.

Part of the willingness to strive for technological changes in the United States is probably attributable to the very abundance of economic opportunity here—to the fact that the displacements and disturbances caused by technological changes have produced fewer problems and, therefore, have aroused less resistance. Be that as it may, there is no doubt that American industry has been operating in an environment far friendlier to technological change than the European. This has had much to do with the attitudes of American managers and American workers toward technological change.

The lack of class organization and social stratification. The lack of highly developed social organization has been favorable to industrial progress. People in the United States are not born into more or less well-defined classes. The idea that it is "unbecoming" for a young man to attempt to rise above his station is foreign to the United States. Hence a young man here does not have to be bold or original to go into business for himself. There are no more or less organized groups of merchants or manufacturers whose ranks ordinary workers have not been expected to aspire to join. The absence of social stratification has helped produce a large number of business births here, and this has given established enterprises the stimulus that comes from having to meet the competition of new and aggressive concerns.

The scarcity of capital and labor in relation to natural resources. The scarcity of capital and labor relative to abundant natural resources has been important partly because it stimulated the accumulation of capital, and partly because it has encouraged American industry to use a large amount of capital per worker.

The reason for the relative scarcity of capital and labor is, of course, that the continent was vacant and its resources rich. The great accumulation of capital during the last century and the enormous increase in population has greatly reduced the scarcity of capital and labor relative to natural resources. Nevertheless, the scarcity of capital and labor has had lasting effects on the economy: It gave a strong incentive to accumulate capital; the high return on capital facilitated the accumulation of capital; the scarcity of labor relative to natural resources made possible a high output per man-hour in comparison with other countries; and each worker had a large quantity of natural resources to help him produce. Consequently, even from early days, the productivity of labor (and also the compensation of labor) has been much higher in the United States than in Western Europe. It is important to notice that the high productivity of labor, relative to Europe, and its high compensation existed here even before the rise of modern industry.

The original high productivity of labor in agriculture in the territory that is now the United States had an important influence upon the technology of nonagricultural industry. One of the problems of city employers in early America was that their workers were inclined to leave them and take up farms. To hold their workers, employers in nonagricultural industries had to pay high wages. Because urban industries in the last several generations have been attracting people from farming, it may seem strange today to talk about agriculture's competing with city employment for labor. In the early days of the country, however, the city industries had trouble holding labor.

This early competition between industry and agriculture for labor tended to make the goods produced by urban industries high in price in relation to the prices of farm products. Furthermore, the high wages that American manufacturers had to pay to hold their men made their goods high in comparison with foreign manufactured goods. Until about 1875, the merchandise imports into the United States usually exceeded exports from this country. Until about 1860 more than half of the merchandise imports were manufactured goods, and until 1875 more than one-third were manufactured goods. Today, manufactured goods are less than one-fifth of all merchandise imports. During most of the nineteenth century, however, American manufacturing had the benefit of stiff competition from European countries. American manufacturers endeavored to get protection from this competition by higher tariffs, but not until the Civil War were they able to get really high tariffs. Hence they had a strong incentive to be efficient.

To pay labor high enough wages to keep it from going into agriculture, and at the same time meet the competition of European manufacturers, American industry was forced to use a large amount of capital per worker. In the early days, much of this capital came from abroad. Although the original conditions that encouraged American industry to use large amounts of capital per worker tended to disappear as the country grew older, the industrial habits established in the early days of the country persisted and affected the later practices of industry.

Another important result of the great abundance of natural resources was the strong stimulus to unusual daring and initiative in industry. There were other conditions, such as the rapid growth in population, that helped to develop these same qualities in businessmen, but the underlying one was the abundance of natural resources. The rewards for opening to population the rich agricultural lands of the Middle West and for developing such resources as the white pine or the iron ore of the Great Lakes, or the petroleum of Pennsylvania and Ohio were very great. Although the rich rewards stimulated vigorous—often unscrupulous—competition, they fostered habits of great initiative and enterprise among businessmen.

The suitability of the land in most parts of the United States for small owner-conducted farming. This was not true of much of the South, or later of much of the West, but it was true of the North and of the Mid West. This condition was of great importance determining the kind of economic philosophy t developed in the United States and also the kind markets that developed here.

Because most agriculture in the United States conducted by owner-operators, the economic philoso of the country was the philosophy of small busin men—men who attached great importance to be independent and to getting ahead by one's own effo It was not the philosophy of a class of well-to-do wealthy landlords who were more interested in enjoy life than in getting ahead, although there were regi where such a class existed. But the philosophy independence and of getting ahead that was indi nous to the farmers of the North and Middle W was ideal for developing the kind of ambitio enterprising town and city businessmen that country needed. A flow of ambitious country b soon started moving to the towns and cities.

The kinds of markets developed by the own operated farms in the days when most of the work of the country were engaged in agriculture also h important effects upon city industries and their te nology. The farmers were not rich, but they produ considerably more than a bare subsistence, and th were numerous. Consequently, they provided a go market for large quantities of semiluxuries. Th technology in the United States from early in the ni teenth century was given the opportunity of produc large profits by meeting the needs of a middle-cl market. Textiles, shoes, stoves, household furnit could all be sold in large quantities provided they not cost too much.

Contrast the middle-class market that grew up in North and Middle West with the kinds of markets th have developed in those parts of the world where lar scale agricultural operations are advantageous, where there has grown up a small class of wealthy la owners and a large number of farm laborers who ceive bare subsistence wages. The well-to-do la owners and their families provide a market for limi quantities of handmade luxury goods. The v number of poorly paid workers provide a mar mainly for foodstuffs of the cheapest kind, as well cheap textiles. Neither of these markets will suppor large expansion of machine industry, such as occur in the United States in response to the middle-cl market that was originally provided by the owners many thousands of owner-operated farms.

The large population in a free-trade area. This i condition that has developed gradually as the coun has grown. By 1830, however, the population of country was nearly 13 million and by 1860 over million. This was larger than the population of European country of that time with the exception Britain, France, and Russia. The large markets op to American manufacturers have provided strong

to use specialized and semiautomatic machines
lso to specialize labor-manufacturing methods
re distinctively American and that have been
to greater extremes here than anywhere else.

rapid growth of the country. Many people today
forgotten how rapidly the population of the
y was increasing during most of the nineteenth
y. For the first six decades, the increase ran
than one-third every ten years, then for three
s it dropped to one-fourth, and finally, in the last
of the century, to one-fifth. The population,
was 5.3 million in 1800, was 23.2 million in 1850
.0 million in 1900.

rapid expansion of the country has stimulated
crease in output per man-hour and thus has
to raise the standard of living. In many other
ies, however, the opposite has been true—in
countries the growth of population has held
the standard of living. The reason is that the
se in population in those countries has occurred
conditions that prevented it from encouraging
cumulation of capital or the improvement of
logy.

he United States, however, the growth of popu-
has stimulated both the increase in capital and
velopment of technology. The principal reasons
een that the country has had large, undeveloped
ces and that a large part of the increase in
tion until recently has consisted of immigrants
king age. Hence, the increase in population has
nted to a considerable extent both an immediate
se in productive capacity and also an expansion
potential markets for goods. It has tended,
ore, to make both labor and capital scarce in
n to markets. The scarcity of labor and capital
used great efforts to raise the productivity of
y improving methods of production. As I have
ed, this scarcity has minimized the dislocations
ed by technological changes and has thus kept
the opposition to change.

rapid growth of the country helped also to
ate a high business birthrate and increased the
als among newly started enterprises. This meant
he proportion of fairly new concerns in each
ry was high. The newly started enterprises are
hat are least dominated by tradition, that have
st adherence to conventional patterns. Hence,
h ratio of new enterprises to all enterprises has
to make industry progressive.

n all the various conditions that have made for
roductivity in American industry are considered,
impressed by the fact that a *combination* of
ions rather than merely the separate conditions
lves have produced the high productivity of
ry here.

e have been other new countries in North
a and South America where both labor and
have been scarce in relation to natural resources
here established traditions were weak. But these
countries have not achieved the high productivity of the United States. One important difference between these other countries and the United States was that settlements in the other countries were developed under the close supervision of European governments, not by people seeking religious liberty. Another important difference was that conditions in most other countries were not favorable to the growth of small owner-operated farms. Hence these countries did not produce the philosophy adapted to owner-operated businesses and there did not grow up in them middle-class markets.

Recent Influences

As I have pointed out, some of the conditions that explained the high productivity of American industry have disappeared or are disappearing. For example, immigration is no longer large, labor and capital are far less scarce in relation to natural resources than formerly, American manufacturing is no longer receiving the strong stimulus from European competition that it felt during much of the nineteenth century, and the rate of growth of population, which has been of great importance in stimulating the economy, is slowing down. In the decade of the twenties, the increase was 16.1 percent; in the thirties, 7.2 percent; in the forties, 14.5 percent. Although the growth of population during the next decade or two will considerably exceed recent estimates, the rate of increase will probably not be greater than about 15 percent per decade, in comparison with substantially higher rates in the nineteenth century. In addition, stiff increases in income taxes have greatly diminished the gains that are to be achieved from starting new enterprises and building large and successful businesses. Do these changes mean that the country will be less successful in raising output per man-hour than it has been in the past?

Probably not. Although some conditions that helped make American industry highly productive are disappearing, others are remaining; and during the last thirty years some new causes for high productivity have developed. The lack of class organization and social stratification persists. A large number of new business enterprises are started each year. Furthermore, the United States has a far larger population in a free-trade area than any other country except Russia, India, and China. This, as I have pointed out, is of great importance because it means that technological methods that would not pay in smaller markets can be used here. The size of the American market is not measured by the number of people alone; per capita income is also important. The high per capita income combined with the large population means that it is economic to use highly mechanized methods for making many kinds of goods, particularly durable consumer goods, that could not be produced economically by these methods in smaller markets. Finally, during the last generation there has been an enormous spread of technological research. Such research is stimulated by the large markets that can be tapped by cheaper or better goods. Such research both produces competition and is also stimulated by competition, and competition helps keep the economy progressive. If one enterprise engages in research, its rivals must do likewise or be left behind. Consequently, the rapid growth of industrial research seems destined to continue. The large markets of the United States also improve the opportunities to apply in civilian industry some of the technological discoveries that are produced by military research.

Present Requisites

It would be unfortunate, however, if the people of the United States were to become complacent about the possibility of maintaining a rapid increase in productivity. There are some conditions that retard the rise in the productivity of the economy. One of the most important of these pertains to the survival of new enterprises. Although the number of new concerns started each year is large, a high proportion fail to survive more than two or three years. It seems clear that the men whose ability and experience best qualifies them to go into business for themselves tend to stay with established concerns. This is understandable because the best qualified executives in existing concerns have the best prospects for promotion. Furthermore, on retirement most of these executives will qualify for pensions. Why should they leave the security and good prospects of their present jobs for the
risks of starting new enterprises? Finally, it is also p
that the facilities for providing capital for new e
prises are far from adequate.

It would be highly stimulating to the econom
well-qualified men started more new concerns
were to grow into larger enterprises. Such conc
would grow partly by taking business away from o
firms. Each would be compelling other concerns t
more alert and progressive. As a result, all enterp
would seach far more vigorously for new and che
methods of production and they would strive ha
to improve their products. This is not the place to
line the various steps that might be taken to incr
the number of well-qualified persons who go into t
ness for themselves; but a program to improve
quality of business births is one of the great need
the country.

The American economy has been progressive
hence constantly growing in productivity bec
Americans have always had a healthy dissatisfac
with things as they are and they have been willin
try something new and different. If Americans as
to keep output per man-hour rising as rapidly as it
increased in the past, they must not become satis
with their economy; they must be on the lookout a
times for weak spots in it and for ways in which it
give consumers more and better goods for less mo

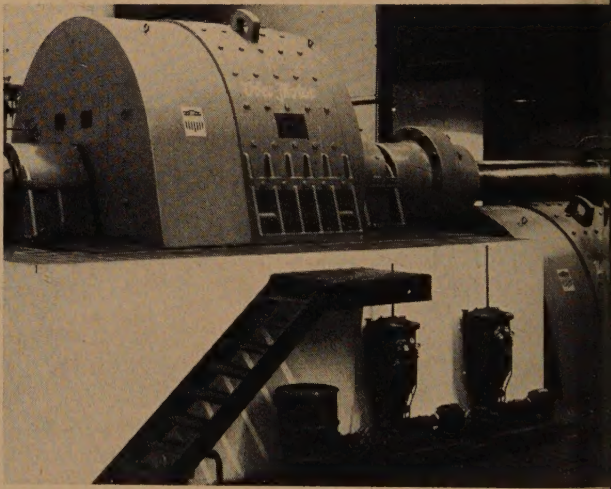
HIGH LIGHTS AND SIDE LIGHTS

Steel Mill in the Alps

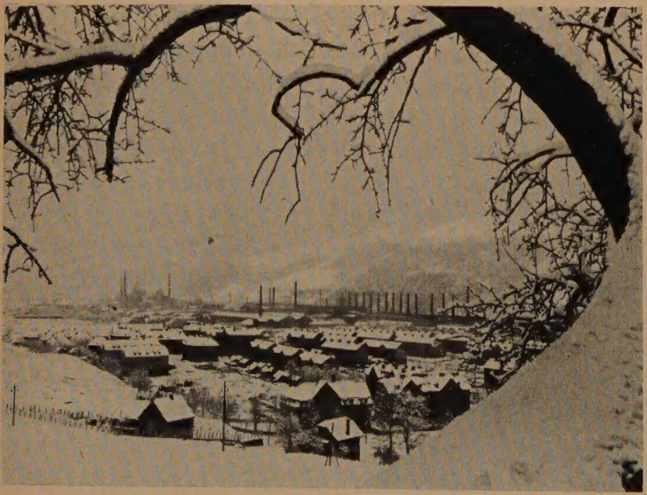
A new $7,380,000 steel blooming mill has made the Oesterreichisch-Alpine Montangesellschaft steel works in Donawitz, Austria, one of the most modern in Europe.

Located in the American zone of occupation within 50 miles of the Iron Curtain, the mill replaces one dismantled by the Russians in 1945 as war booty. The new facility was financed by ECA funds. Scheduled to furnish 60 percent of Austria's crude steel, it is designed for a capacity of 75,000 tons of steel monthly.

The twin mill drive uses two 4000-hp d-c motors operating on 800 volts. These
single-armature reversing motors pro
8000 hp at 50 rpm, with a maximu
120 rpm and a peak load capacity of
percent. The motors can be reverse
the 50-rpm level in less than two seco



Twin mill drive (8000-hp) in operation in the new blooming mill



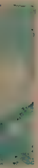
Newly equipped steel works located in the Mur Valley in the Austrian Alps

Supplying power to the motors
flywheel motor-generator set which
cludes a 6000-hp 500-rpm wound-r
induction motor, four 1750-kv d-c gen
tors, and a steel-plate flywheel wit
stored energy of 185,000 hp-sec at 500 r

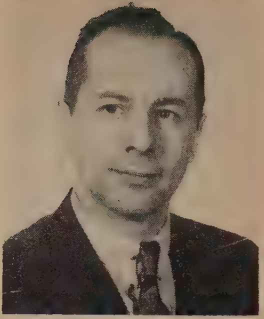
Officials of the Austrian firm hope f
production of nearly a millions ton
steel annually within the next thre
four years. The maximum output of
old mill was less than half of this.

EVISION BROADCAST ANTENNAS

Overcoming problems encountered in transmitting 4 million cycles of intelligence per second as a signal for television receivers. Major antenna requirements and the need for continued development



By J. E. KEISTER
Electronics Division
General Electric Company



J. E. Keister

LEVISION is becoming one of the greatest in-ences in American life today and it appears to ven greater potentialities in the future. Approxi- 12,000,000 sets are now in the hands of the In the order of four persons may be watching t, which gives a viewing audience of 48,000,000 The impact of drama, novelty acts, sports, and ings of national interest are changing the leisure of the nation. In areas where television trans- are operating today, it is a common sight to eiving antennas sprouting on almost every roof. e remote locations, miniature towers are seen ting elaborate arrays in an effort to obtain signals in this new medium.

nsmitting Antenna

problem of laying down a signal which the re- antennas can use is of utmost importance. The ty of producing power at all at the high operating ncies of TV is great. It becomes even greater, ring that the transmitter must deliver 4 million of intelligence per second, or almost 4 times the standard broadcast band. The transmitting a which transforms this precious power into a available for the receiver has a major role to play.

equirements

ddition to many minor problems the design of a on antenna must overcome two major ones: The n absolute must, is that it present the correct nce to the transmission-line feed over the oper-requencies with a tolerance in the order of 5 percent; the second requirement is that the power of the transmitter be directed to cover the landscape where the receiving antennas are located with the maximum possible signal. Energy directed skyward is of no benefit to anyone. For a transmitter located centrally with respect to its audience, the desirable radiation pattern would be a saucer-shaped field with its maximum energy directed toward the horizon. (Fig. 1.)

The thinner this shape of energy can be made, the less energy will be lost, and the greater will be the received energy at the remote locations where the need is greatest. The only limitations on this are mechanical in nature, either because of difficulty of construction or difficulty in reducing tower sway with wind. Occasionally, with respect to immediate surroundings of very high antenna locations, a weak spot, or null, close to the antenna has been observed. This is the exception, however, and it can be overcome by making a relatively slight change in part of the antenna.

Antennas with a considerable degree of horizontal directivity are desirable when located at one edge of a service area. These have not found wide usage, however, partly because of the difficulty of producing such an antenna, and partly because the actual gain to be realized with the directivity which can be tolerated is relatively slight.

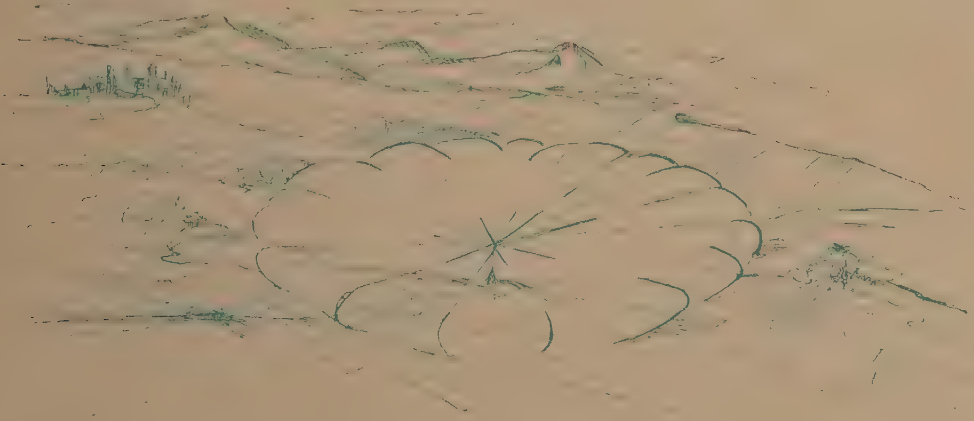


Fig. 1. A sketch showing the omnidirectional radiation pattern of a television antenna

Antenna Impedance

Many approaches have been taken to produce antennas which overcome the serious problem of presenting a correct and constant impedance over a very

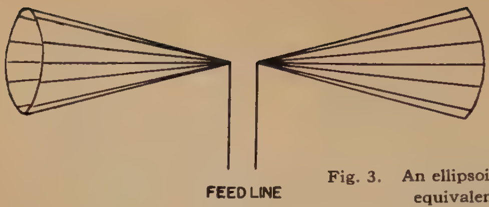


Fig. 2
Carters' cones

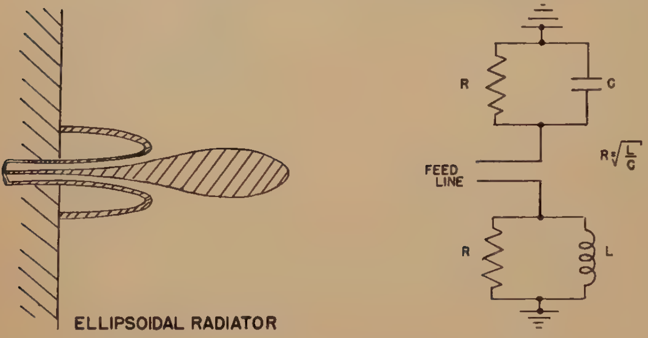


Fig. 3. An ellipsoidal radiator and its equivalent circuit

wide frequency range. A traveling-wave (nonresonant) type of antenna terminated in its characteristic impedance provides the most enticing solution to this problem. The well-known rhombic⁽¹⁾ is an example of this, but it has the drawback of being very directional and therefore not particularly suited to broadcasting. Much effort and ingenious design has gone into making resonant antennas to achieve the desired resistance with wide-band characteristics. The Carter's Cones⁽²⁾ (FIG. 2) and other fan-type structures represent an approach to this by so distributing the shape of the radiating elements as to maintain an almost uniform current along them.

The prewar WNBT ellipsoidal radiating elements⁽³⁾ were arrived at empirically to simulate the well-known constant-resistance network where the radiation resistance in each arm is equal to the square root of the inductance-capacitance ratio (FIG. 3). This gave a phenomenally wide band in the order of 60 percent of its center frequency, but it was expensive and difficult to support generally.

Quarter-wave Technique

Many variations of dipoles, loops, squares, etc., have been undertaken where compensation techniques were used for reducing the rapid impedance change with frequency. A favorite trick in this connection is to use the impedance inversion characteristic of a quarter-wave transmission line. If an impedance is placed at the remote end of such a line, it will appear at the driving point as

$$Z_1=\frac{Z_0^2}{Z_2} \qquad (1)$$

where Z_0 is the surge impedance of the line and Z_2 is the load impedance (FIG. 4).

Paralleling Z_1 with a second Z_2 gives a combined impedance of

$$Z_T=\frac{Z_0^2Z_2}{Z_2^2+Z_0^2} \qquad (2)$$

If now Z_2 is made approximately equal to Z_0 c

$$Z_2=Z_0(1+\delta)$$

(where δ may be complex) then

$$Z_T=\frac{Z_0}{2}\,\frac{(1+\delta)}{\left(1+\delta+\frac{\delta^2}{2}\right)}$$

or to a first approximation

$$Z_T=\frac{Z_0}{2}$$

This, of course, holds only as long as the l
electrically a quarter wave and δ remains mucl
than unity in absolute magnitude. In practice, thi
remarkably well at covering up shortcomings i
radiating elements themselves when identical rad
are connected together through such a quarter-
line.

Superturnstile Antenna

An important by-product of this quarter-
technique with dipoles or their variations is tha
two elements are automatically driven in time-
quadrature. If they are also placed at 90 deg in
relationship and the combination viewed from a re
location, there is observed what appears to b
electric vector rotating synchronously with the c
frequency and with nearly a uniform amplitude i
horizontal direction. The result is a happy marria
wide band and omnidirectivity which is known
"turnstile" antenna.⁽⁴⁾

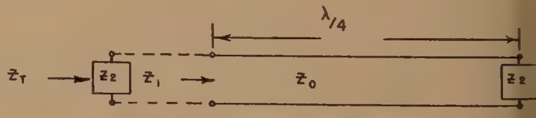


Fig. 4. A quarter-wave transformer

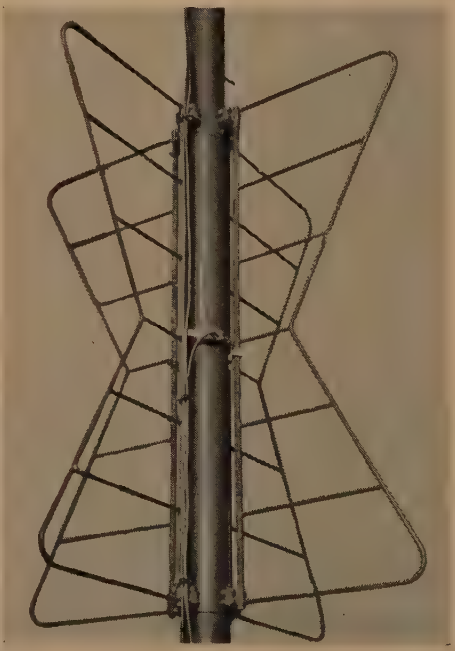


Fig. 5
Superturn
radiator

⁽¹⁾Numbered references are listed at the end of the article.

superturnstile antenna (FIG. 5) was again lly derived,(5) this time as a radiating element rcuited to the supporting structure at both ends ven in the middle as a half-wave resonant line. er proportioning of the appendages hung along , a more or less uniform vertical current dis- n was obtained which, as will be described later, l more vertical gain or compression of the g field than the simple dipole. In addition, this proved to be sturdy and simple to construct, deice, and was selfgrounded against lightning.

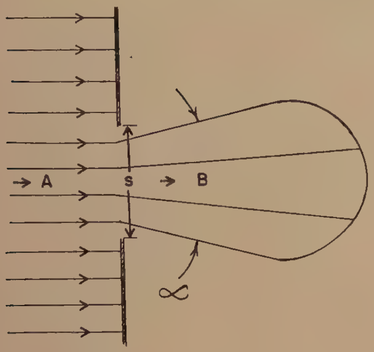


Fig. 6. The effect of an aperture on the radiation field

Directivity

tion can now be given to the problem of vertical ity or gain, where there are some rather basic ons on the gain that can be achieved for any ertical dimension of radiating system. Note the diagram in FIG. 6 and consider, for a moment, a uniform parallel radiating field in the region A encountering an infinite sheet of absorbing material with an aperture S in the vertical direction.

The field in the region B will be diverging, and the angle of divergence (at the half-power points) will be

$$\alpha=\frac{51\lambda}{S} \text{ degrees} \tag{6}$$

where λ is the wavelength of the energy. Obviously, the smaller the value of α the more concentrated will be the energy and the greater the field on the horizon. From the standpoint of an observer, in the region B and remote from S, the condition is the same whether the field came from behind a sheet or was generated at S by currents in conductors. Because of the immediate concern with antennas, the important things are uniform in-phase currents over large values of S. Equation (6) represents a rule-of-thumb ultimate goal of antenna design.

he 12-bay superturnstile antenna at WHAS, Louisville (Kentucky)

The most common practice is to stack a number of radiating elements vertically and attempt to drive them all in phase (as viewed from any given horizontal direction). Ordinary dipoles whether large-diameter, conical, or specially shaped require large numbers for good utilization of vertical pole dimension because the illumination occurs in "lumps" rather than being uniformly distributed.

On the other hand, the superturnstile antenna is particularly well suited to uniform illumination because each element produces a long *vertical* distribution of nearly uniform current. The WHAS television antenna(6) at Louisville (Kentucky) has demonstrated the feasibility of carrying this to 12 bays at 200 mc (FIG. 7) which gives a vertical aperture of nearly 100 ft and an effective power gain of over 12. To insure exact phase and equal distribution of power to each element, they are fed from a common junction box with equal lengths of cable, the excess of which is coiled up for the near elements.

Transmitting in the UHF Field

In the UHF field (470 to 890 mc), the problem of bandwidth becomes less severe because the video or intelligence band (4 mc) remains fixed and therefore a smaller percentage of the operating frequency. At the same time, however, the need for higher gains is even greater than at the lower VHF channels. One approach is the pyramiding of large numbers of resonant slots cut in a vertical pole and fed from a central conductor.(7) These slots are cut in groups of four located at 90-deg intervals around the pole and driven in time-phase quadrature so that again the effect is the equivalent of a turnstile producing a rotating relatively uniform radiation field. Although this achieves a relatively high gain, it becomes difficult to balance and tune each slot. This technique has been carried to the extent of 24 bays or 96 slots and a power gain of approximately 17 obtained.

The Helical System

The most promising approach to the UHF-TV transmitting antenna appears to be the "sidefire" helical system.(8) Here advantage is taken of the wide impedance bandwidth characteristic of a traveling-wave type of radiator (untuned). The radiator is a wire or rod coiled about the supporting pole. The diameter of the helix is so chosen that the circumference is an integral number of wave-lengths. Thus, when viewed from any azimuth angle, the current in the visible portion of each turn is in phase with every other. By adjusting the pitch of the helix, this provides as smooth an illumination of the vertical aperture as desired. Because of this pitch, there will be a vertical component of field from a single helix. To overcome this a second helix, spiraling downward but in the same direction of winding as the upward one, is fed jointly. This provides a vertical component in opposition, hence cancelling. The horizontal component, on the other hand, aids the first helix. The radiation per turn is determined by the spacing from the pole, thus making a sufficient number of turns; the energy at the far end becomes so negligible (having been radiated) that it can be left open, grounded, or treated in any desired manner. Shown in Fig. 8 is a single-bay helical radiator.

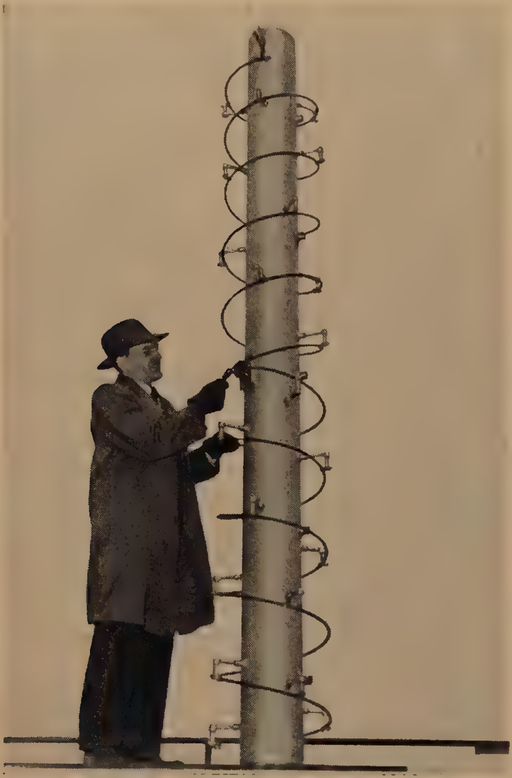


Fig. 8. A single-bay high-gain helical radiator

To achieve more gain, it is necessary only to add more bays or sections, being careful only to feed each in phase with the others. By inserting a rigid copper tube in the mast, a coaxial transmission line is achieved from which energy can be coupled to the helix. This transmission line can be solidly short-circuited one-quarter wave below the primary line feed point and one-quarter wave above the last take-off point c
radiators. The result is a mechanically simple,
structure. Even the tower beacon light obtai
power from cable passed through the inner c
tube. Lightning protection is achieved by s
grounding the upper end of the top helix to the
and tying adjoining ends of adjacent helices tog
The small picture at the beginning of the article s
a four-bay UHF helical antenna.

The questions of wind loading and deicing are
present. The successful antenna is usually the
which best solves these problems while still achi
the required electrical characteristics. The super
stile lends itself to deicing the critical section b
insertion of a Calrod* heater in the tube paral
the pole. Wind loading is cut to a minimum b
use of as few struts as possible in the element.

The helical antenna is deiced by passing low-vo
high-current AC through the copper-clad steel r
the helix from a transformer at the bottom o
antenna to the grounded top end—the ultima
simplicity. In addition, wind loading is very low,
principally that contributed by the pole itself.

Development Possibilities

The field for TV antenna development is still
Perhaps the least explored area is that of special
zontally directive patterns. Certain types of sym
cal patterns such as a figure eight, footprint, etc
be obtained by time-phasing the turnstile types
than in quadrature around the pole. Some typ
dipole systems with built-in ground planes(9)
produce asymmetrical patterns but these have th
advantage of high wind loading.

A degree of "umbrella" shaping to the othe
pancake nature of the field can be obtained by c
ing the relative phase of various bays of stacked a
With the helical, this can be done by simply rot
one bay mechanically with respect to the o
Always welcome, however, will be an antenna eas
build and adjust, having high controllable gains
vertically and horizontally which place a minim
strain on the supporting structure.

References

(1)"Horizontal Rhombic Antennas," by E. Bruce, A. C.
and L. R. Lowry, *IRE Proceedings*, vol. 23, Jan. 1935, p. 2
(2)"Simple Television Antennas," by P. S. Carter, *RCA R*
vol. 4, Oct. 1939, p. 168.
(3)"Television Transmitting Antenna for Empire State
ing," by N. E. Lindenblad, *RCA Review*, vol. 3, April, 19
387.
(4)"The Turnstile Antenna," by George H. Brown, *Elect*
vol. 9, April, 1936, p. 15.
(5)"Super Turnstile Antenna," by R. F. Holtz, *Communic*
April, 1946, p. 40.
(6)"Engineering a Super-gain TV Antenna," by M. E.
Television Engineering, Part I, vol. 2, May, 1951, p. 16; P
vol. 2, June, 1951, p. 18.
(7)"Ultra-High-Frequency Antenna and System for Tele
Transmission," by O. O. Fiet, *RCA Review*, vol. II, June
p. 212.
(8)"Side-Fire Helix UHF-TV Transmitting Antenna," by
Krause, *Electronics*, vol. 24, Aug. 1951, p. 106.
(9)"High Gain and Directional Antennas for TV Broadcas
by L. J. Wolf, *Broadcast News*, vol. 58, March-April, 1950.

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*Reg. trade-mark of G.E. Co.

HOTOMETRY . . . . . . Part II

Use of the spherical photometer for measuring the luminous flux of incandescent and fluorescent lamps

By M. H. GABRIEL, C. F. KOENIG, and E. S. STEEB, JR.

Standardizing Department, Lamp Division
General Electric Company

OR to July, 1950, the unit of light had never en established by law in the United States. In the National Bureau of Standards, by agree- with laboratories in France and Great Britain, uced the International candle. This agreement, er, did not provide for any primary reference rd. Pending the development of a satisfactory tandard, the "candle" was represented by groups bon-filament lamps. As other types of lamps were ped, working standards of the new types were independently in various countries. This required comparison of lights of different colors, which is difficult, and led to some diversity of units. ver, Germany and Austria never accepted the ational units of light.

STANDARDS OF LUMINOUS FLUX

er years of discussion and experimental work on rds of candlepower and on the photometry of of different colors, general agreement was reached points: first, the best type of primary standard vailable is a radiator of the type known as a body, at a temperature controlled by molten um at its freezing point; second, lights of dif- colors should be evaluated by means of certain rd luminosity factors representing the spectral vity of the average eye under specified conditions.

se two elements give a basis for a complete system tometric units when a numerical value is assigned brightness of the platinum black-body standard. ghtness expressed in international units was ex- entally determined to be 58.9 candles per square eter. In 1936 the National Bureau of Standards sed that the round value of 60 c per sq cm be d as defining a new basic unit, to be extended ts of other colors by means of the accepted sity factors. This proposal was approved by the l States National Committee of the International ission on Illumination after favorable recom- tion by a committee including representatives of nerican Institute of Electrical Engineers, Illumi- Engineering Society, Optical Society of America, al Electrical Manufacturers Association, Edison c Institute, Association of Edison Illuminating Companies, Electrical Testing Laboratories, and lamp manufacturing companies.

This new system of units was adopted by the International Committee on Weights and Measures in 1937 and approved by ICI in 1939, but because of the war the execution of the plan was delayed until January 1, 1948. Then on July 21, 1950, the 81st Congress approved Public Law 617, giving legal status to these photometric units.

Magnitude of Units

The light from the platinum black-body radiator is not greatly different in color from that given by carbon-filament standard lamps; the color of the lamp filaments is about 2100 K, whereas the freezing point of platinum is 2046 K. In this range of color, the new unit of intensity is about 1.9 percent smaller than the old international candle, and sources of light are given correspondingly higher numerical ratings. However, when light sources of higher color temperature are compared with these basic standards, the accepted spectral luminosity factors give slightly lower values for the whiter sources than were obtained by visual measurements when the international units were established. The difference between the two scales therefore decreases as the color temperature of the sources measured is increased, and for sources in the range of ordinary vacuum tungsten-filament lamps, around 2500 K, the new scale crosses the international scale used in the United States. Furthermore, when the range of standards was extended to gas-filled tungsten-filament lamps and other new types, the measurements were made by methods nearly in accord with the luminosity factors. Consequently the present ratings of tungsten-filament lamps in this country was practically unaffected by the change, no type being changed by more than one percent.

Current Practice

Since these units have now been legally established, and since the Bureau of Standards is recognized as the authority for maintaining these basic units, any laboratory engaged in making photometric measurements should establish and maintain an agreement with them.

This can best be done by acquiring from the Bureau groups of photometric standard lamps which they have calibrated and certified. These lamps should be specially constructed and selected for the purpose to assure stable

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nued from the GENERAL ELECTRIC REVIEW, vol. 54, no. 9, Sep- 951, "Photometry: Part I," by M. H. Gabriel, C. F. Koenig, and eb, Jr.

values, and should, of course, also be properly seasoned before they are submitted for certification.

The types of standards required depend somewhat on the kind of lamps being measured. In general, it is a good practice to employ standards having approximately the same characteristics as the lamps being measured. This will minimize some of the errors caused by poor receiver linearity and sphere integration. It is also recommended that no fewer than four lamps be used to represent any particular type, and that they be properly preheated and operated in the same burning position in which they were certified.

Since standards, like any regular lamps, change throughout life as they are burned, it is advisable to avoid excessive burning. One way to prolong the certified values on a group of basic standards is to make from them a group of secondary, or working, standards for everyday use. The basic standards can then be put away and used only for occasional comparisons with the working standards. This practice is recommended especially where a considerable amount of photometric work is done.

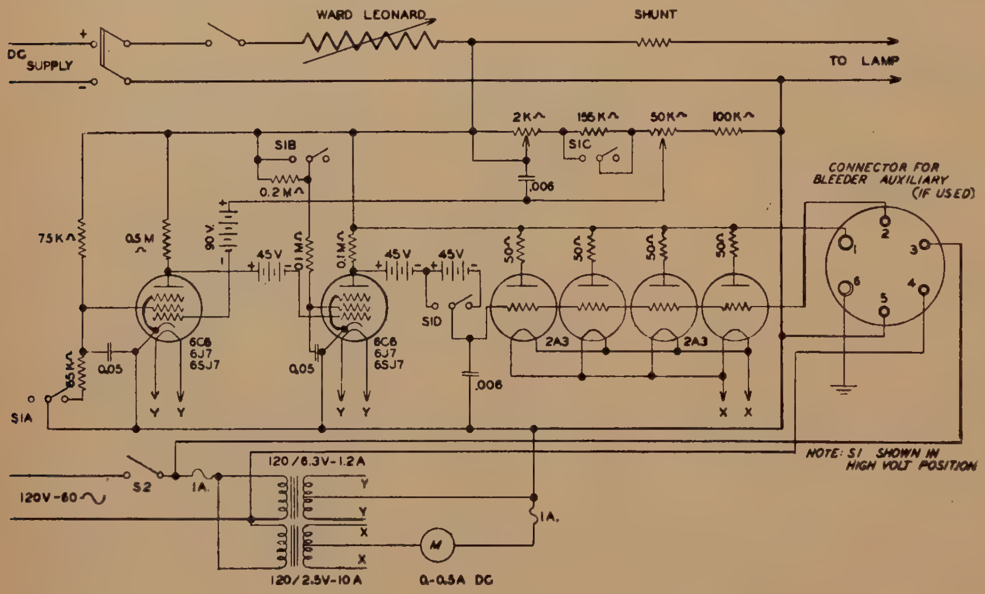


Fig. 10. Bleeder voltage-regula circuit

Gaseous Lamps as Standards

Gaseous-discharge lamps can be used as standards, but should be calibrated by a recognized laboratory, under controlled conditions. They should be seasoned for at least 300 hours, and then carefully selected for stability of operation and physical appearance. The spectral characteristics of the photometer are not so important as long as the standards are of the same color and size as the lamps that are to be measured This sometimes involves a great number of standards.

The main disadvantage in using discharge lamps as standards is that they are not always as reliable and as constant as incandescent standards. The luminous-flux values may vary as much as several percent, even though all precautions seem to have been taken.

Incandescent-filament standards are preferred for their constancy and reliability of operation. Their luminous-flux characteristics remain substantially stant for repeated operation. They are not affecte ambient temperature or wave-form distortion, reach stabilization in a very short time, thus spee up the calibration of the photometer.

However, the spectral difference between incan cent-filament lamps and gaseous-discharge lamps m it necessary to use gaseous-discharge lamps as stand unless the spectral characteristics of the paint, rece filter combination, and differential absorption been carefully determined.

Change in Mercury-vapor Standards

The National Bureau of Standards announced luminous flux values for mercury-vapor lamps in 1950. The General Electric Company adopted new values in August, 1950.

This revaluation places the mercury-vapor lamp basis consistent with incandescent and fluores lamps. Values of luminous flux for fluorescent and candescent lamps were changed slightly Januar 1948, following the new international agreement. change was generally less than one percent for regular types of lamps, but the 1950 revaluatio mercury lamps was much greater: 9 percent l for 400-watt and 4.5 percent lower for 250-watt la

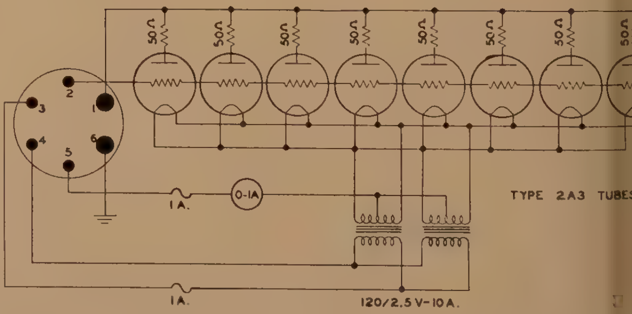


Fig. 11. Auxiliary circuit used to extend voltage-regulator current ra

The new change in values for mercury-vapor la was due primarily to improvements in photom

ique. The original standards were calibrated by
National Bureau of Standards by direct visual
parison with incandescent standards in force at
time. This comparison is one of the most difficult
ne visual photometric problems, because of the
difference between the spectral distributions of
nt flux in the two types of light sources. Light
the incandescent source gives continuous spectrum
ughout the visible range. Light from the mercury-
r lamps is concentrated largely in the yellow,
, blue, and violet regions of the spectrum, which
es it almost impossible to obtain a good color
h.

is difficulty in color matching and the different
acteristics of the human eyes were the chief causes
he discrepancy between the incandescent and
ury-vapor lamp values. The development and im-
ements of the physical photometer have made it
ble to evaluate these mercury-vapor lamps with
greater accuracy.

PHOTOMETRY OF INCANDESCENT LAMPS

ost photocell measuring circuits, and particularly
one described in this article, have an extremely
tive response to any slight changes in luminous
Since the output of a lamp depends largely upon
voltage impressed upon it, the power supply, volt-
regulation, and electrical measuring instruments
me important factors in obtaining accurate over-
neasurements. Each of these items is covered in
l in the following paragraphs.

r Supply

has been proved experimentally that the same
ere and luminous-flux values will prevail for an
ndescent lamp, whether they are measured on
nating or direct current. From the standpoint of
ation and control, however, a d-c supply lends
more readily than a-c. This power can be obtained
r from a group of storage batteries or from a
r-generator set, provided that it is equipped with
ltage regulator to compensate for any line dis-
nces caused by varying load conditions or com-
tor fluctuation.

e relative merits of a battery vs. a motor-gener-
are mostly a matter of economy. The initial cost
maintenance of a group of batteries usually are
derably higher than those of a generator. In all
respects, either will give a satisfactory perform-

e voltage regulator described here is of the elec-
type and, when used with suitable control rheo-
will work equally well with either battery or gen-
r within the limits of its capacity. This particular
ator, which was designed and built in the Lamp
ng Laboratory, will accommodate lamps in either
20- or 240-volt range, having a current rating of
han 3.0 amp. Regulation is within ±0.01 percent
the range of 80 to 140 volts on the low scale and
260 volts on the high scale.

An auxiliary has also been developed which, when used in conjunction with the regulator, extends the range to 8.0 amp. The wiring diagrams for the bleeder and auxiliary are shown in FIGS. 10 and 11. When high-ampere lamps are read, the auxiliary plugs into the bleeder proper by means of the connectors shown in the diagrams.

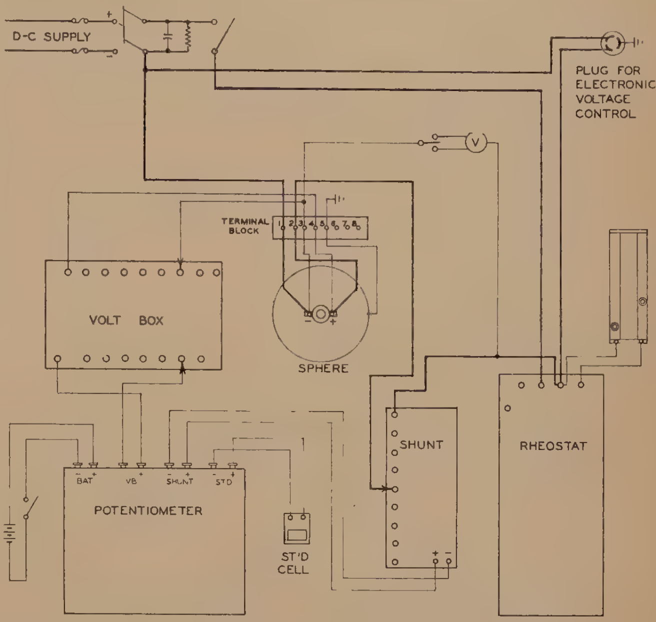


Fig. 12. Complete electrical circuit of the incandescent-lamp photometer

These regulators are connected across the d-c supply on the load side of the control rheostats as shown in FIG. 12. The regulator will then bleed some current through the rheostat that will be in addition to the current taken by the lamp. If the voltage across the lamp and regulator tends to rise, the regulator will draw more current through the rheostat, and in this way reduce the voltage at the lamp to its correct value. Conversely, if the voltage tends to fall off, the regulator will draw less current through the rheostat, thereby raising the voltage to its original value.

Instruments

Another factor in favor of d-c operation is that, in general, it permits the use of d-c instruments which have desirable characteristics for this application.

The ratio of luminous flux to voltage is of the order of four to one. Since the photoelectric receiving circuit described in this article has an accuracy of 0.1 percent, it becomes necessary to employ electrical instruments having a proportionately comparable accuracy. This suggests the use of either laboratory standard meters or potentiometers.

In this instance it was considered expedient to use potentiometer equipment, and for the purpose the Brooks type deflection instrument was selected. This instrument has an over-all null reading accuracy of ±0.02 percent. The volt box extends the range of the potentiometer from 0 to 150 millivolts to include these voltage scales: 0–1.5/3.0/7.5/15/30/75/150/300 volts. With the addition of the multi-range shunt, it is possible to obtain 0–0.75/1.5/3/7.5/15/30/75/150-amp scales.

With this equipment, and proper power supply, it is possible to measure any electrical values encountered in lamps ranging from the smallest flashlight types up to the limit of the circuit and the instruments.

FIG. 12 shows a complete layout of the various power-control and measuring units arranged in their proper order for operation as shown in FIG. 1 (Part I, in GENERAL ELECTRIC REVIEW, Sept. 1951). These are composed of the following items:

Sphere (30-, 60-, 80-in. dia as needed)
Potentiometer (Brooks type)
Volt box for potentiometer
Shunt for potentiometer
Standard cell
Storage battery (4-volt wet type)
Rheostat (Ward Leonard)
Tubular rheostat (900-ohm, 0.7-amp)
Tubular rheostat (55-ohm, 3.3-amp)

Seasoning

All incandescent lamps pass through a period of slightly rising luminous-flux characteristics during the early part of life. This is caused by a realignment of the crystalline structure of the filament and a change of the surface condition as the die marks disappear through evaporation and redisposition.

Such transformations may result in changes of as much as 5 to 15 percent, with luminous values usually reaching stability in less than 15 hours, burning at normal volts. From there on the lamps are quite stable except for the gradual decline in output throughout life.

In view of this it is necessary to preburn (season) all new lamps before attempting to measure them for the first time. Seasoning at normal voltage is preferred, because it conforms to the manner in which the lamps are used and also because seasoning is primarily a matter of time rather than degree of forcing with higher voltages.

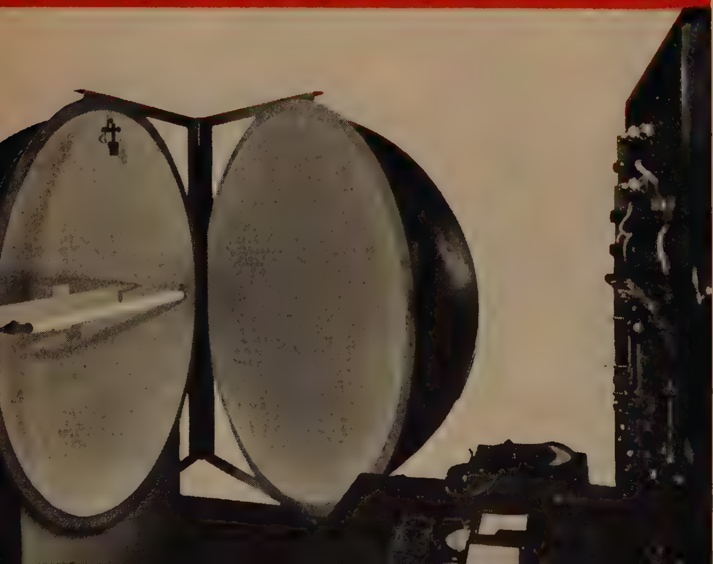


Fig. 13. Interior of the sphere of a fluorescent-lamp photometer

Preheat

Even though seasoned, most lamps also requi short period of operation before accurate measurem can be made. The time required varies somewhat, cording to the size and construction of the indivi lamp.

Small lamps, 7½ to 25 watts, will stabilize al immediately, whereas some of the larger types, hav heavier filaments and lead wires, may require u five minutes of burning before stability is reached. example, laboratory practice is to preheat 40-w incandescent lamps one-half minute, the 100-watt la one minute, and the 500-watt lamp two minutes.

Interval Measurements

All lamps show a depreciation in light out throughout life, due in part to the blackening of bulb.

For this reason it becomes necessary to make m urements at certain intervals throughout the life of lamp in addition to those made initially. These m urements are means of evaluating the quality of a la from the standpoint of its performance or lumen m tenance throughout life.

When making measurements on blackened lamp a sphere, certain precautions must be taken. When opaque or light-absorbing medium is placed in sphere after it has been calibrated, the losses indu by absorption of light from the multiple sphere- reflections will reduce the illumination on the meas ment window. The magnitude of this error varies depends on the relative size of the sphere and blackened lamp.

Compensation for these losses must be made by differential-absorption test described in the Theor the Sphere section in Part I.

PHOTOMETRY OF FLUORESCENT AND OTHER DISCHARGE LAMPS

The photometry of fluorescent and other disch lamps is so different from that of incandescent-filan lamps that it is necessary to treat it separately.

The integration sphere photometer is used for ability to accurately integrate all of the luminous developed in the test lamp. Adequate precaut should be taken to assure proper diffusion of inte surfaces, placement of baffles, and combined spec response of receiver filters, measurement window, the sphere as an integrator.

The size of the sphere depends, of course, on the of the lamps to be tested. For example, the lengt the lamp under test should never be greater than percent of the inside diameter of the sphere. It is sirable to so construct the sphere that one hemisp can swing open, allowing the lamp, especially fluorescent type, to be easily inserted in the la holders (COVER). This also makes the sphere more ac sible for painting and for cleaning. The sphere instrument table used in measuring fluorescent la are shown in FIGS. 13 and 14.

ne sphere should be equipped with a center socket nted on an arm that can be raised or lowered to center of the sphere to accommodate lamps with ium or mogul bases. There should be two sliding s, one from each side of the sphere, which will ort the fluorescent lamps. A support should also ncluded to hold the baffle. This can be a tight wire ss the stationary hemisphere. Fluorescent lamps usually photometered horizontally; other types of cury vapor lamps are photometered in the position which they were designed.

ne receiver should be in an enclosure, mounted on outside of the sphere, and usually in the central of the stationary hemisphere. A small section of sphere wall in front of the receiver mounting should ut out and diffusing glass installed. This diffusing s becomes the "measurement window." The receiver the color filter are the same as those used for ndescent photometry.

incandescent-filament standards are to be used he calibration of the sphere, d-c power is desirable. can be supplied from storage batteries or from a motor-generator. If a generator is used, then a lator is necessary. Such a regulator is described in il in the section on Power in the Incandescent p Photometry section of Part I. Proper tubular stats are sufficient for adjusting the d-c supply. boratory-type voltmeter or potentiometer should be for setting the proper voltage to the standards.

uments

ne potential coils of the wattmeter and voltmeter on the lamp, or secondary, side of the circuit ld be of the high-impedance type, measuring RMS es. The instruments used on the line, or primary, can be of lower impedance, provided that the er meter losses are calculated and corrections made. erience has indicated that potential coils with an edance of 150 ohms per volt are satisfactory for the att and higher-wattage lamps. Instruments with ntial coils of higher impedance would be desirable; ever, such instruments are less reliable. The smaller- age lamps should be measured by the "light ration" method or with a meter amplifier. The lifier, when used with the potential coils of the meter and voltmeter, must not distort the wave or cause any phase shift.

nly one instrument should be in the circuit at a in addition to the instrument which is used to tain the lamp voltage or current. A properly main- ed switch (with a very low voltage drop) should be lled in the meter circuit for the purpose of cutting nstruments in and out of the circuit.

Restoration

ne potential element of the wattmeter should be nnected that the wattmeter measures the loss of lement. The power diverted by the instruments in ircuit is difficult to determine. Perhaps the best method in determining this diversion is the light-restoration method, as follows:

After a lamp has become stabilized on normal line volts, and with only the primary voltmeter in the circuit, record the light output of the lamp, and (1) place the wattmeter in the circuit and read; then restore the original light output to the lamp by increasing the voltage and (2) remeasure the lamp watts. The loss E^2/R of the potential coil should be subtracted from the second measurement, and if this corrected result agrees with the uncorrected first result, the wattmeter can be used without any corrections for losses. The losses in the other instruments can be determined in the same way.

Amplifier

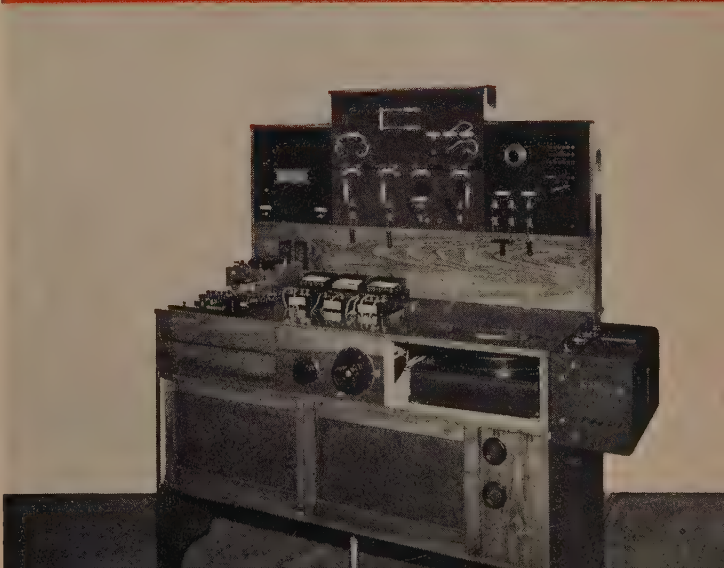
The amplifier described in this article was manufactured by The Keithley Instruments and is known as Model 104 Meter Matcher. This is a stabilized amplifier with a very low internal output impedance. Its main purpose is to permit the use of accurate, low-impedance voltmeters and wattmeters on relatively high-impedance circuits. The meter matcher will develop 150 volts across a 2000-ohm load at frequencies from 20 to 600 cps.

The meter matcher will operate with voltmeter or wattmeter potential coils having impedances as low as 2000 ohms. The output voltage to the meter will be a linear function of the input voltage within 0.15 percent. The current drain from the signal source will never be more than 150 microamp.

Alternating-current voltmeters and wattmeters accurate to 0.1 percent usually have low impedances, some requiring as much as 10 watts input for full-scale deflection. The use of such meters on high-impedance circuits is not desirable, because of the errors introduced by the meter current. Therefore, in order to use these accurate meters in fluorescent-lamp circuits, a meter matcher or amplifier of some sort is necessary.

The combination of the meter matcher and accurate low-impedance meters is the most accurate method of determining the electrical characteristics of fluorescent lamps, especially the lower-wattage types.

Fig. 14. Instrument table used with the fluorescent-lamp photometer



Power Supply

The supply should be substantially a true sine-wave source. The presence of excessive harmonics may have serious effects on photometric results.

The supply should also be as steady and free from sudden changes as possible. The exact value of the line voltage is not critical, since it is necessary to incorporate a variable-voltage autotransformer in the circuit for voltage adjustments.

Experience indicates that the static-type voltage stabilizers, although perfectly satisfactory from the standpoint of voltage control, usually distort the wave shape so much that it is impossible to obtain accurate electrical readings in a fluorescent-lamp circuit unless adequate corrections of wave shape can be obtained through a suitable filter.

Reference Ballast

A reference ballast is an inductive-type ballast that is designed, manufactured, and maintained for the purpose of providing a comparison standard for use in testing commercial ballasts or for testing fluorescent lamps.

A relatively accurate device, the reference ballast is characterized by constant impedance over a wide range of operating current and is relatively uninfluenced by time, temperature, magnetic surroundings, etc. Although this ballast is designed to be fairly rugged, it must be handled with caution in order to avoid undue physical abuse, such as dropping onto a hard surface, shipping in insufficient packing, or overloading electrically.

The reference ballast has been established as the point of reference from which lamp measurements are made and from which commercial ballasts are specified. In lamp measurements, after the voltage and frequency of the power supply are specified, the lamp is operated in series with a reference ballast. These general parameters then determine the operation of the lamps. In ballast specifications, the commercial ballast is designed to deliver to a reference lamp the same characteristics within limits as is delivered by the reference ballast. Thus photometry and electrical measurement of a lamp on a reference ballast are tied in with the operation on a commercial ballast.

An example of the establishment of a reference ballast for a newly designed lamp may serve to illustrate the point. Assume that a lamp has been designed whose current for best operating characteristics has been determined, and that the circuit voltage across the lamp and ballast has been established. A lamp which meets these specifications is then operated in series with an adjustable reactor across the specified voltage, and the reactor adjusted until the specified operating conditions for the lamp are obtained. A linear reactor of this impedance will then be a reference ballast for that particular lamp.

The American Standards Association has set up specifications C82.3 covering the circuit voltage and the reference-ballast impedance for all the fluorescent lamps in ordinary use. By following these speci tions, any individual can adjust his own refer ballast. If it is preferred, the reference ballast ca sent to the Electrical Testing Laboratory, Inc., York 21, New York, for adjustments.

Seasoning

Gaseous-discharge lamps pass through a rapid dec in luminous flux during the early part of life, usu caused by some of the mercury getting into the pl phor or the glass or both. This decline can resul changes of as much as six to eight percent, and usu levels off after 100 hours of operation.

Lamps are also more unstable before burning, and that reason it is a general practice to burn all gase discharge lamps for 100 hours before rating. The hour results are actually considered the initial rat

Lamp Starting

Preheat-start lamps should be started manua This can be done by inserting a switch between two pins located on each end of the lamps. A sr capacitor should be connected across the switc 0.006 µf for the 40-watt and smaller sizes, and 0.0 for the 85–100-watt sizes.

The preheat current should be sufficient to cause glow in the lamp after 2–3 seconds of preheating. If lamps are started before proper preheating, or heated at too high a current, the lamp may spira develop hot spots or cause other improper operat of the lamp.

Warm-up or Stabilization

Even lamps that have been seasoned require a sh warm-up, or stabilization, period. Measurements be made when the luminous flux and electrical char teristics become stable. This usually requires from minutes, for the smaller lamps, to twenty minutes, the larger lamps. An exception is the sodium lamp, wh requires at least forty-five minutes for stabilization

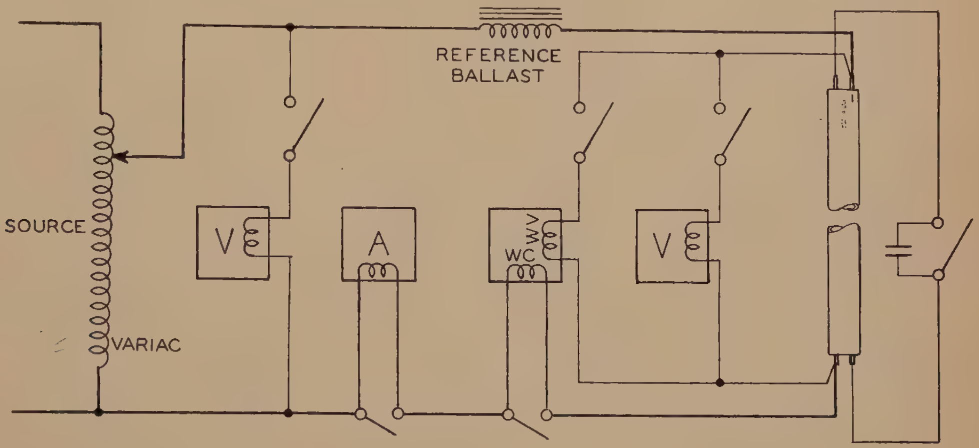
If discharge lamps are stabilized in the sphere, c should be exercised to avoid a rise in temperat within the sphere, due to heat generated by the lar This can be assured by leaving the sphere open u the measurements are ready to be taken. If the lar are stabilized outside of the sphere and transferred i the sphere, care should be taken not to rotate the lar but to place it in exactly the same position as dur the stabilization period. This applies only to fluoresc lamps; sodium lamps should not be disturbed af stabilization has begun, and not for one hour after power has been turned off. Disturbance of the la while warm may cause improper distribution of condensing sodium.

Lamp Connections

The lamp position in the measuring circuit sho be fixed, and proper marking of the pins should be u for power connections. Either the cross-over or parallel scheme of pin connections can be used (cr scheme preferred), but the adopted scheme should lowed consistently in the measurement, seasoning, ny life testing of the lamps. A recommended cir- s shown in FIG. 15.

ient Temperature

e luminous flux and electrical characteristics of arge lamps are affected by ambient temperature drafts. This can be as great as approximately 10 nt for an ambient temperature change from 75 F F. Eighty degrees Fahrenheit has been considered



Electrical circuit for fluores- cent-lamp photometry

e standard temperature in the measurement of lamps.

e ambient temperature should be controlled with- F, and drafts should be avoided.

Spiralling

roper operation by a lamp is one of the chief s of discrepancies in determination of the correct ous flux and electrical characteristics when all factors are correct.

Spiralling, hot spots, swirls, etc., can usually be detected visually, but there are also invisible, or incipient, spirals that cannot be detected by eye. These can be discovered by running a small permanent magnet along such a lamp, causing it to brighten enough at any spot where the incipient spiralling exists, so that it is visible to the eye. Turning the lamp off for approximately fifteen seconds and restarting will usually eliminate the trouble.

Lamps operating incorrectly tend to have a higher operating voltage and wattage, and also in many cases show a small fluctuation on the instruments.

Summary

The objective of this article has been to describe the instrumentation and test methods for measurement of luminous flux developed to date and presently in use in our Lamp Testing Laboratories. Other methods have been tried and perhaps still others are in use elsewhere. Experience in the Laboratory has not yet revealed a simpler or less expensive means of accurately determining luminous flux of light sources.

(*Concluded*)

GHTS AND SIDE LIGHTS

Induction Heater—Ups Production, Cuts Costs

of the induction heater is reported manufacturer to have cut by 70 the cost of hardening coupling Used for hardening the bolts after ing, the induction heat process also hem correct hardness and distor- e properties. This has eliminated erations, and in turn reduced cost. nother installation, a company cut st of reclaiming valuable metal rom rejected weather stripping by an 90 percent with a 5-kw induc- ater.

d been found that, because of the ty of getting rubber to adhere to 20 to 30 percent rejects could be d. Reclaiming the valuable metal from these unsatisfactory pieces merly done by soaking the strips for several hours in a highly inflammable chemical solvent, after which the swollen rubber could be peeled off by hand.

In the new set-up, the rejected strips are carried on a continuous conveyor belt through an inductor coil connected to an induction heater, and are stripped immediately by a gloved workman. The heater runs six to seven hours a day, processing nearly six thousand strips in that time. The cost for power is approximately 80 cents per eight-hour day. The induction heater, the company reports, paid for itself in the first month it was used.

Use of this induction heater has cut coupling-bolt hardening costs 70 percent, and gives distortion-free hardening of each piece

TANTALYTIC CAPACITORS

Levin W Fost

The Tantalytic* capacitor has proved notably useful on the basis of cost, size, and performance, and is expected to fill the need for a high-grade electrolytic capacitor

By L. W. FOSTER
Capacitor Division
Transformer and Allied Product Department
General Electric Company

SINCE World War I the trend in electronic equipment has been to smaller and lighter equipments. Among the reasons for this trend are the need for increased convenience, efficiency, and mobility. In 1918, with the components then available, it would have been impossible to build a radio receiver and transmitter the size of a package of cigarettes. Today, with all the kinds of miniature components being produced, it can be done quite easily.

However, welcome though this trend in equipment may have been to the ultimate user, it has presented the capacitor manufacturer with three extremely difficult problems:

(1). How to reduce capacitor size without sacrificing reliability

(2). How to overcome the high temperature created as the capacitor size is reduced and its ability to dissipate heat is lessened

(3). What to do when the practical limits in size reduction of common paper-impregnated and electrolytic capacitors have been reached

When these problems were recognized, a program of research for their solution was started; and it became apparent that there was a definite future for tantalum metal in improving electrolytic capacitors. The basic studies having been completed, progress has been rapid; and Tantalytic capacitors are now on a limited production basis.

Tantalytic Capacitors

Tantalytic is the General Electric trade name for a foil-type electrolytic capacitor the electrodes of which are made of the metal tantalum.

It was developed for low-voltage d-c applications where the performance of aluminum electrolytic and paper capacitors has not been entirely satisfactory. It is a small-size lightweight and sturdy capacitor with long shelf and operating life. The Tantalytic capacitor has already gained widespread acceptance in the communication fields, both military and civilian.

Theory of the Electrolytic Capacitor

Basically an electrolytic capacitor consists of
conducting plates, separated by insulating mate
immersed in an electrolyte and enclosed in a suita
container. To explain the theory of such an appare
simple unit, however, it is best to start with an
more simple unit—the common type fixed paper
pregnated capacitor—and work up.

The fixed paper impregnated capacitor consists
two conducting plates (called electrodes) to which
attached suitable terminals for making electrical
nections. These electrodes are separated by an i
lating material known as the dielectric. FIG. 1 sh
schematically the construction of such a unit.

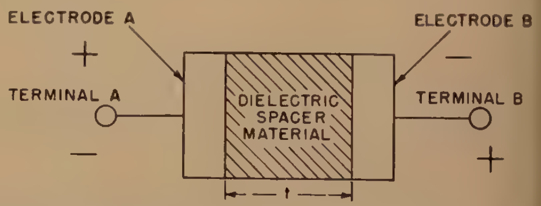


Fig. 1. Cross-sectional representation of terminals, electrodes, diele
tric, and spacer materials of conventional capacitor

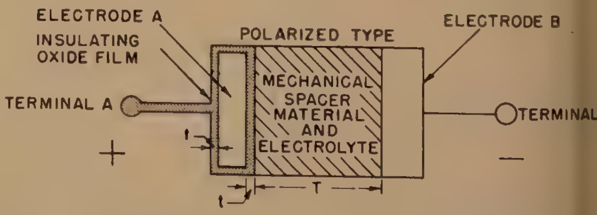


Fig. 2. Terminals, electrodes, dielectric and spacer materials
polarized type of electrolytic capacitor

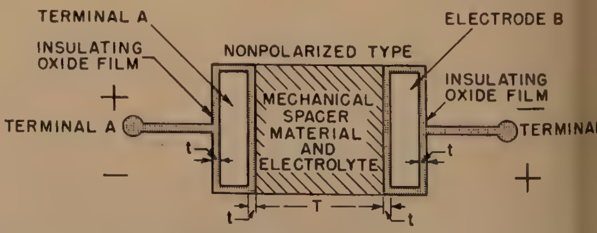


Fig. 3. Terminals, electrodes, dielectric and spacer materials for n
polarized type of electrolytic capacitor

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*Reg. trade-mark of G.E. Co.

e electrical performance and characteristics of paper-impregnated capacitors are determined, in nain, by three things:

(1). The thickness *t* of the dielectric material
(2). The area of the electrodes
(3). The specific inductive capacity of the dielectric terial, commonly referred to as dielectric constant.

wever, the size of the completed unit is also a r consideration; therefore capacitor engineers e to make the dielectric thickness as small as ble and to select a dielectric material with as high lectric constant as possible. In paper capacitors, al dielectric thickness of approximately 0.0004 in. practical minimum, and materials having a dielec- constant of 3 to 6 have been found to be most ble. To achieve the effect of a thinner dielectric, lectrolytic principle must be used.

G. 2 shows the component parts of an electrolytic capacitor—that is, the terminals *A* and *B*, two rodes, and spacer material. It will be noted that e paper capacitor (FIG. 1) the dielectric material he spacer material constitute the distance *t*. How- in the electrolytic capacitor (FIG. 2) the spacer rial is not a part of the active dielectric. The ctric material in this case is a thin insulating oxide having the dimension *t*. In the electrolytic capac- it is the distance *t* which determines the magni- of the electrical capacitance obtainable. The spacer rial, dimension *T*, acts as a conducting spacer be- n the oxide film dielectric and the opposite elec- . In the Tantalytic capacitor the dimension *t* is ngstroms per volt (10^{-7} cm per volt).

the paper capacitor, terminal *A* or *B* may be ive or negative electrically; therefore, it may be l a nonpolar capacitor. In the electrolytic capac- (FIG. 2) the electrode *A*, which is coated with an insulating film, is designated as having a plus rical polarity; therefore, such a capacitor is a type—one with a definite electrical polarity.

obtain a nonpolar electrolytic capacitor that is ble for reversal of polarity, it is necessary to form electrodes (*A* and *B*) with an insulating oxide (FIG. 3). When terminal *A* is positive (+) and inal *B* is negative (−) the insulating film on elec- *A* acts as a capacitor while the spacer material as a conductor. Similarly, when electrode *A* is ive and electrode *B* is positive, the dielectric film ectrode *B* acts as a capacitor while the spacer acts effective short circuit. Therefore, with such ection it is possible to make electrolytic capacitors behave in a nonpolar fashion. Note that in the type electrolytic capacitor the active dielectric ness is equal to *t*, while in the nonpolar capacitor 3) the active dielectric thickness works out to ual to 2*t*. Since amount of capacitance is inversely rtional to the dielectric thickness *t*, for the same ness of insulating oxide film the nonpolar electro- capacitor will have one-half the capacitance of the type for equal size.

ELECTRICAL ASPECTS

To clearly visualize the electrical operational characteristics it is convenient to devise an equivalent circuit, composed of lumped electrical constants. The polar-type Tantalytic capacitor is thus represented in FIG. 4:

R_1 = resistance of terminals and electrodes
R_2 = (represents) a-c power loss in dielectric oxide insulating film
R_3 = effective resistance of spacer material and electrolyte
R_4 = (represents) equivalent leakage currents
C = electrostatic capacitance of insulating oxide film
L = magnetic inductance of terminals, electrodes, and capacitor geometry.

In practice R_1 can be quite accurately calculated by using Ohms' Law and the resistivity values and physical dimensions of the metals involved in the terminals and electrodes.

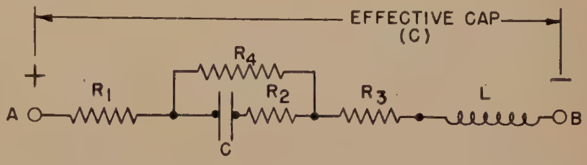


Fig. 4. Equivalent circuit for polar-type electrolytic capacitor

The value for R_2 can be estimated from the power-factor values of the insulating oxide material. In tantalum oxide (Ta_2O_5) the power factor is generally less than 0.1 percent over a very wide frequency range. Therefore, in applications of electrolytic capacitors this dielectric loss is generally neglected.

The value of R_3 is determined by the chemical and physical properties of the spacer and electrolyte materials. The value of R_3 in general determines the resistance characteristics of the Tantalytic capacitor.

The value of R_4 is determined by the chemical and physical condition of the insulating oxide film dielectric. In practice this value is made as high as possible by proper chemical processing and careful manufacture.

The value of R_4 will vary greatly with:

(a). Time of electrification
(b). Thermal history of capacitor
(c). Temperature
(d). Ratio of formation to rated voltage
(e). Manufacturing processes.

As already explained, the nonpolar Tantalytic capacitor will have one-half the capacitance of a polar-type Tantalytic capacitor; therefore, a nonpolar capacitor will require twice the electrode area to have an equivalent electrostatic capacity rating. Hence, the values for L, R_1, R_2, R_3, and R_4 will be different for polar and nonpolar capacitors.

The equivalent circuit for the nonpolar capacitor, using the same symbols as used for the polar type (FIG. 4) is shown in FIG. 5.

For practical reasons it is necessary to combine the various resistance components into a single series value R which is designated as the "series resistance" of the capacitor. On this basis, the equivalent circuit for both polar and nonpolar type capacitors is as shown in FIG. 6.

In general, Tantalytic capacitors are used for capacitance values ranging between 0.1 and 100 μf. In such applications the effect of the inductance L may be neglected and the equivalent circuit reduced to that shown in FIG. 7. The value of R may be obtained from measured power-factor values (PF),

$$R=\frac{(\mathrm{PF})10^6}{2\pi f C} \quad \text{ohms}$$

where C is in microfarads and f is in cycles per second.

The value of C is determined by:

(a). Formation voltage
(b). Area of electrodes
(c). Polar or nonpolar types

From experimental results it has been determined that, for a polar-type capacitor having a formation voltage of 200 volts, an area of 3.05 sq in. of anode is required to give one microfarad of capacitance. From these data the effective dielectric constant (K) may be calculated as follows:

$$C\ (\text{in}\ \mu\text{f})=\frac{0.224\ (\text{the anode area in sq in.})\ K\times10^{-6}}{t\ \text{in inches}}=1$$

$$t=200\times10^{-7}\ \text{cm}=79\times10^{-7}\ \text{inches}$$

whence $$K=\frac{79\times10^{-7}}{0.224\times3.05\times10^{-6}}=11.5$$

Tests by optical means indicate a K of approximately 11.3 for Ta_2O_5.

For many applications it is more convenient to use the over-all impedance of a capacitor. The impedance is a function of the capacitance C, inductance L, and series resistance R and is generally denoted by the symbol Z.

$$Z=R-j(X_C-X_L)$$
$$R=(X_C)\ (\text{Power Factor})$$
$$j=\sqrt{-1}$$
$$X_C=\frac{1}{2\pi f C};\ C \text{ is in farads, and } f \text{ in cycles per second.}$$
$$X_L=2\pi f L;\ L \text{ is in henrys, and } f \text{ in cycles per second.}$$

For most applications, L may be neglected, hence, we may find the magnitude of Z as follows:

$$Z=\sqrt{R^2+X_C^2} \quad \text{ohms.}$$

CHEMICAL ASPECTS

The phenomenon generally called "electrolytic valve action" occurs in an electrolytic cell when in one direction it offers a high d-c resistance when the anode is positive and a very low d-c resistance when the anode is negative. In other words, the device is an electrical

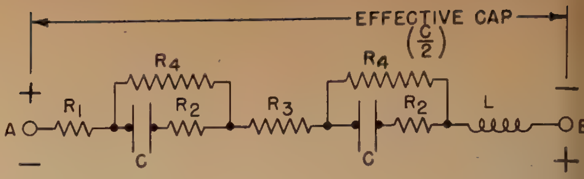


Fig. 5. Equivalent circuit for nonpolar-type electrolytic capaci

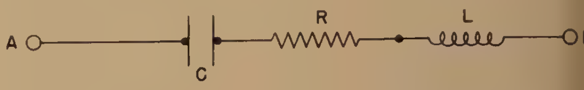


Fig. 6. Equivalent circuit of capacitor, with lumped constants

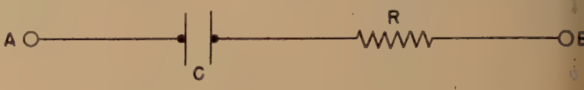


Fig. 7. Equivalent circuit of capacitor, inductance neglected

rectifier. The most perfect valve action of an elec lytic cell occurs when the d-c resistance of one pola is zero and the opposite polarity infinity.

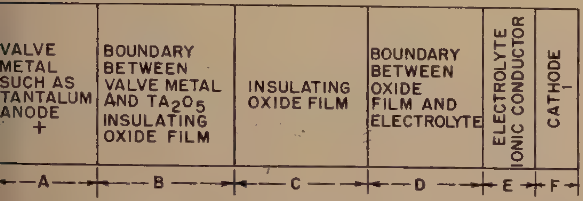
This phenomenon was first observed with oxidi aluminum and led to the development of the conv tional aluminum electrolytic capacitor. Later on it found that a more perfect electrolytic valve act takes place with tantalum. Imperfect valve action ta place when the amount of dissolved valve metal notably affects the intended performance; and the perfect valve action of aluminum is largely due to fact that this metal is not totally insoluble in m electrolytes. The more perfect valve action of tantal means that the solubility of the valve metal in electrolyte is so slight that it does not affect intended performance.

The electrolytic cell is formed when a suitable va metal anode (+) is immersed in an electrolyte toget with a suitable cathode (−) electrode. The appl tion of a polarizing potential with anode positive a cathode negative causes an oxide film to be built on the anode. The nature of the electrolytic oxide f built up by this process depends on the kind of va metal used and the chemical and thermal conditi within the electrolytic cell. In tantalum valve me the insulating oxide film produced electrically is Ta At the start of the formation process with a fi potential value, the current is very high; and as insulating oxide film is built up the current gradua diminishes to a low value for valve metal electrol cells. The electrical, chemical, metallurgical, and ther conditions required to produce good capacitors extremely critical.

There are many theories as to how valve action ta place within an electrolytic cell. One way to expl this action is based largely on the electric potentia field theory.

The action of the electrolyte cell may be bro down into the regions shown in FIG. 8 as A, B, C, E, and F. When A is positive and F is negative, electrical stress on the insulating oxide film is appro mately 19,000 volts per mil for the Ta_2O_5. Thus

tric potential between the base valve metal *A* and
oxide film *B* must be very much greater than
00 volts per mil. Also the stress on boundary *D*
veen the oxide film *C* and the electrolyte *E* must
very much greater than 19,000 volts per mil. At
i potential stresses electrons will flow due to "work
ential" functions of the valve metal. When the
le is positive, electrons must flow from electrolyte
alve metal *A* but since the electrolyte is largely
c in nature, few electrons are available, little elec-
current flows and the result is a blocking action of
electric current. When the anode *A* is negatively
rized there are plenty of electrons available in the
e metal to flow and plenty of positive ions in the
trolyte to carry the electrons to the cathode *F*.
s when the anode is negatively polarized large cur-
s flow and effectively short-circuit the electrolytic
From this theory it can be predicted that the


VALVE METAL SUCH AS TANTALUM ANODE +
BOUNDARY BETWEEN VALVE METAL AND TA_2O_5 INSULATING OXIDE FILM
INSULATING OXIDE FILM
BOUNDARY BETWEEN OXIDE FILM AND ELECTROLYTE
ELECTROLYTE IONIC CONDUCTOR
CATHODE −
A
B
C
D
E
F

. 8. Block diagram of vital regions within an electrolytic capacitor
t

ndaries between valve metal and oxide film *B* and
veen oxide film and electrolyte *D* perform very
lamental functions in electrolytic-cell action. There
uch evidence to indicate that the proper chemical
physical conditions of these boundaries determines
life span of electrolytic capacitors.

ne other important chemical phenomenon in Tanta-
capacitors is the sparking-voltage level. Slug-type
citors constructed with very strong acid electro-
s are limited to voltages under 100 volts d-c because
higher voltages small electric arcs occur. This
cillation destroys the capacitor in a very short time.
king conditions are again the result of chemical
litions at the boundary regions *B* and *D*. Electrolytes have been developed which are neutral chemically and which have greatly increased sparking-voltage levels. The high level of sparking voltages obtainable results in a wide range of voltage ratings of Tantalytic capacitors using a single highly standardized and controlled electrolyte. Also a chemically neutral electrolyte greatly aids mass production of Tantalytic capacitors because of the ease of processing and the use of simple casing and sealing techniques.

In the formation of tantalum foils there is a wide variation in color. A typical color-voltage spectrum is given in Table I for direct reflection of light.

TABLE I

R-VOLTAGE SPECTRUM (FOR DIRECT REFLECTION) DISTINGUISH-
ORMATION VOLTAGES IN PREPARATION OF TANTALUM FOILS AT

ormation Voltage at 25 C	Typical Color
0	Grey
10	Golden brown
50	Bluish silver
75	Yellow gold
100	Magenta (reddish-blue)
110	Nile green
150	Yellow
200	Green
250	Light magenta (deep pink)
300	Light greenish cast
350	Nile green
400	Light pink (purplish)
450	Very light pink

MATERIALS USED

The valve metal used in Tantalytic capacitors is the element tantalum, a soft, ductile, gray-white, acid-resisting metallic element of the vanadium family found (combined) in tantalite, columbite, and other rare minerals. The chemical symbol for this metal is Ta, atomic number 73, and atomic weight 180.88; physical weight, 0.6 lb per cu in. It melts at approximately 2990 C and boils at a temperature of over 4100 C.

Baron J. J. Berzelius (1775–1884), a Swedish nobleman and chemist, produced tantalum metal in 1820 by the heating of potassium tantalum fluoride with potassium. The great difficulty encountered in separating this new element led to the adoption of the name tantalum, from the Greek Tantalus, and akin to the word tantalize. W. Von Bolton, in 1905, by high-vacuum process, produced relatively pure tantalum metal. The Fansteel Metallurgical Corporation, after many years of research, have worked out a process for producing high-purity tantalum by an electrolysis of potassium tantalum fluoride. Since tantalum and columbium generally occur in the same ores, one of the greatest problems is to separate these two elements. The Fansteel Metallurgical Corporation method makes it possible to separate columbium from tantalum on a production basis. Primary supplies of high-grade tantalum ore are found in large quantities in Australia, Brazil, and South Africa. There are secondary ore supplies available in the United States and Canada.

Production of Tantalum

The separation of pure tantalum metal results in a finely divided powder product. This powder is pressed into briquettes or ingots, placed in a high-vacuum furnace and heated to a temperature approaching the melting point of the metal. This heating of the pressed tantalum powder under high vacuum causes it to sinter and joins each particle together, forming a porous mass. These sintered slug bars or ingots are then rolled into sheet material having a thickness of 0.005 to 0.01 in. This sheet tantalum is then rolled down by suitable equipment to the desired thickness of foil for fabrication into capacitors.

The chemical process for producing tantalum is extremely difficult and costly, resulting in the finished metal costing approximately ten times as much as the tantalum metal in its natural ore. The cost of tantalum

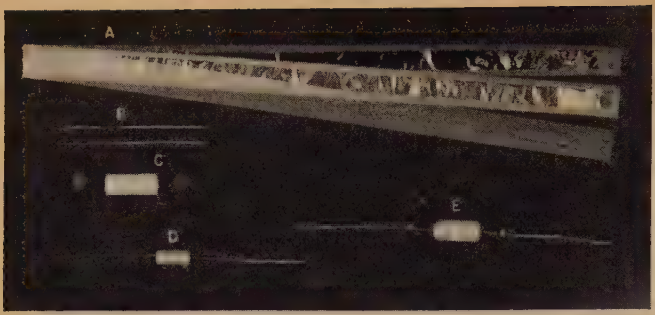


Fig. 9. Steps in the manufacture of a Tantalytic capacitor

- *A:* Two foils separated by insulating spacer material. These parts are fanned out to show their relation
- *B:* Two tantalum leads flattened on one end ready for welding to foils
- *C:* Two rubber seals and a silver-plated copper case
- *D:* Foils and spacer and terminal leads assembled into wound Tantalytic capacitor ready for assembly in case and impregnation
- *E:* Completely assembled Tantalytic capacitor with welded-on solderable leads

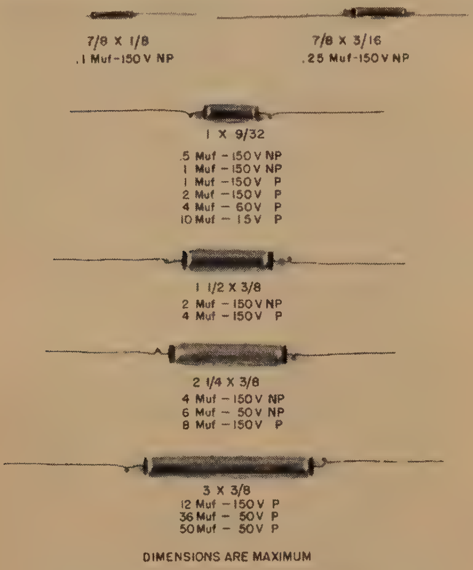


Fig. 10. Ranges in sizes and ratings of Tantalytic capacitor units

foil increases very rapidly for thicknesses under 0.001 in. and it appears that 0.0005 in. is a practical minimum limit.

The rolling of thin tantalum foil is a new art and much experimentation will be required to develop techniques for handling this metal on a large scale. In making aluminum foil for capacitor usage, it was a matter of two decades before processes were found that produced low-cost foil—that is, foil costing under $1.00 per pound. With volume production and further research, the cost of tantalum foil should be reduced greatly; this, in turn, will reduce the cost of tantalytic capacitors.

Capacitors may be made directly by using the sintered porous slug with terminal wires attached and many such type capacitors have been constructed during the past 20 years. The sintered porous slug may be readily formed into shapes suitable for capacitor fabrication, and in low-voltage, small-capacitance sizes of the polar type, sintered porous slug construction produces a smaller capacitor than does foil construction. For the nonpolar type tantalytic capacitors, where the sintered porous cathode and anode areas must be equ there is less volume advantage over the foil construc capacitors. It has been found that, in many electro and communication applications under abnormal op ating conditions, a slight reversal of potentials is countered; and in these cases it is necessary to partia "form" the cathode in order to insure reliable operati Such cathode formation reduces the volume efficien of sintered-type tantalum capacitors. The mean f path between sintered slug anode and cathode is lar and therefore to get the minimum series resistance, a highly conducting electrolyte is required which h the disadvantage, previously mentioned, of bei limited to low-voltage applications.

The foil-type construction makes it possible utilize mass-production techniques already available the capacitor manufacturing art. Also, the wound ty tantalytic capacitor with thin foils offers greater fle bility in design and ease of manufacture.

The economics of the Tantalytic capacitor is large a matter of cost of tantalum foil. At the present ti tantalum foil costs approximately a hundred dollars p pound and a typical polar 1-μf 150-volt d-c capacit requires about one thousandth of a pound. Therefo the tantalum capacitor will cost considerably more th an equivalently rated aluminum electrolytic un However, electrical stability, excellent low temperatu characteristics, long shelf life, and smaller size in ma cases more than offset the extra expense.

Other materials used are tantalum wire for termin leads, porous spacer material, and silver or silver-plat copper cases; also, proper electrolytes for forming a impregnating the capacitor units.

CONSTRUCTION

FIG. 9 shows the several disassembled and assembl stages of parts for a 1-μf 150-volt d-c polar-ty Tantalytic capacitor.

TABLE II

TYPICAL RATINGS AND DIMENSIONS OF TANTALYTIC CAPACITOR UN

Unit	Type*	Capacitance (microfarads)	Volts d-c	Length (inches)	Diamete (inches)
29F401	NP	1	150	1	9/32
29F405	NP	4	150	2¼	3/8
29F408	NP	0.25	150	⅞	3/16
29F416	NP	0.5	150	1	9/32
29F418	NP	0.1	150	⅞	1/8
29F428	NP	6	50	2¼	3/8
29F430	NP	2	150	1½	3/8
29F402	P	1	150	1	9/32
29F403	P	4	60	1	9/32
29F404	P	12	150	3	3/8
29F406	P	8	150	2¼	3/8
29F413	P	2	150	1	9/32
29F414	P	50	25	3	3/8
29F424	P	36	50	3	3/8
29F427	P	10	15	1	9/32
29F429	P	4	150	1½	3/8

* *P* indicates Polarized, *NP* indicates Nonpolarized.

efore tantalum foils are wound into the completed acitor, lead wires or terminals must be attached and anode (positive) electrode "formed" to the desired ree. The terminals are tantalum wires securely led to the foil and extending through the insulating tic stoppers which form the capacitor seals. The de foil and leads are placed in an electrolyte bath positive voltage is applied. This causes a layer of alum oxide to be formed on the surface of the anode. s is the process of "formation" and the thickness of oxide film is proportional to the "forming voltage" lied.

he tantalum oxide dielectric is operated at an elec- al stress of over 19,000 volts per mil, which is prac- l, because of the self-healing properties of the alum film when dielectric breakdown occurs. As as a breakdown occurs in the oxide film of the

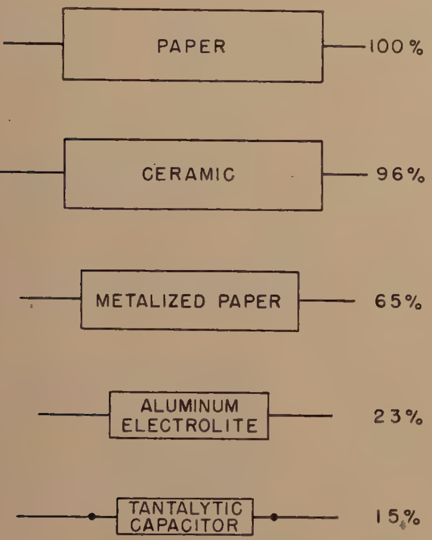


Fig. 11. Comparison of capacitor sizes of 100-volt d-c units. This volumetric relationship is markedly different in higher voltages

rmed" anode material, virgin tantalum metal is un- ered and the process of "formation" immediately ts and repairs the breakdown. There is such a ll amount of heat generated during breakdown that igible damage occurs within the capacitor structure. s high usable stress results in a capacitor having roximately 25 μf per cu in. at 150 volts d-c rating.

es of Construction Arrangements

o illustrate the range of sizes in which the Tanta- c capacitor is currently being manufactured, a cal assortment is shown in FIG. 10 and listed in le II. Many other variations in size and ratings can leveloped.

evelopmental work has progressed so favorably the original pilot-plant facilities have long since n outgrown, although it is still operating to produce ple capacitors for trial applications. The pilot plant osely co-ordinated with further development work g done on tantalum metal and methods for pro- ng lower-cost capacitors.

TYPICAL CHARACTERISTICS AND TEST DATA

FIG. 11 shows a graphical comparison of various types of capacitors and tantalum capacitors of 100-volt d-c rating in terms of percentage of volume. FIG. 12 gives a general size comparison for various types of capacitors as a function of microfarads per cubic inch, and voltage rating. Using Kraft paper capacitors as 100 percent volume, other types are:

Type	Percent Volume 100-volt d-c	 500-volt d-c	 1000-volt d-c
Paper	100	100	100
Ceramic	96	250	400
Metalized Paper	65	535	1330
Aluminum Electrolytic	23	30	67
Tantalytic Capacitor	15	25	50

The complete testing of a new product requires years. Hence, complete technical data on performance of Tantalytic capacitors are not now available. However, many accelerated tests have been made and they indicate long shelf life, low leakage current (high insulation resistance), and good capacitor stability with temperature. Data relating to these characteristics are included in the groups of curves. Electronics engineers will find these curves useful in establishing proper application in electronic and communication equipment. To date, Tantalytic capacitors are being applied in telephone communication equipment, Signal Corps communication equipment, and Ordnance devices. In commercial telephone equipment, the small size and long life of the Tantalytic capacitor are the desirable features, whereas in military and ordnance equipment, small size, resistance to shock, low temperature characteristics, and long shelf life are the most important qualities.

Capacitance vs. Temperature

FIG. 13 gives average values for capacitance versus temperature of Tantalytic capacitors. Curves are plotted for 100 percent capacitance at +25 C and for 60, 120, 1000, 10,000 and 20,000 cycles per second. The amount that the capacitance drops with decreasing temperature is a function of the chemical nature of the electrolyte.

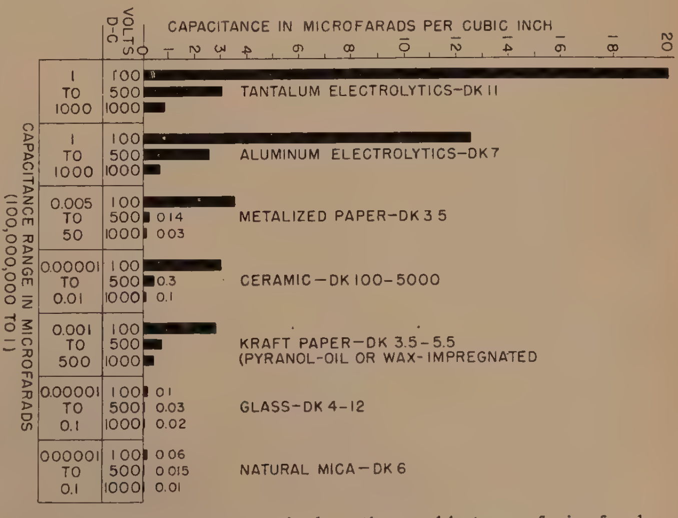


Fig. 12. Capacitance range in d-c ratings and in terms of microfarads per cubic inch

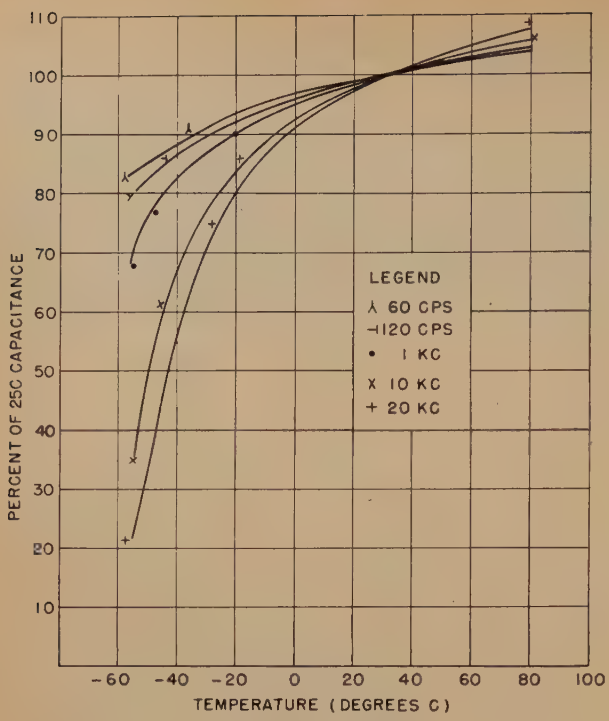


Fig. 13. Percent of 25 C capacitance vs. temperature for several frequencies for one-microfarad Tantalytic units

Capacitance vs. Frequency

Fig. 14 shows the change of 60-cycle capacitance over the frequency range of 0 to 10,000 cycles per second at 25 C. It is in this range of frequencies that Tantalytic capacitors will find widespread application.

Power Factor vs. Frequency

Fig. 15 shows the average power factor of Tantalytic capacitors over the audio-frequency range. (For higher frequencies, Fig. 22 provides data from which the power factor may be computed.)

Leakage Current vs. Time

Fig. 16 is plotted for a one-microfarad 150-volt d-c polar-type Tantalytic capacitor which was "formed" at 200 volts d-c. Measurements at 50, 100, and
volts are plotted in Fig. 16 as a function of ti
Fig. 17 presents the same data except plotted
megohms × microfarads versus time for 50, 100, a
150 volts d-c.

A typical one-microfarad 150-volt capacitor has
effective anode foil area of 1.5 × 2 = 3.0 sq in. At
volts, at the end of ten minutes the leakage current
25 C is 1.1 × 10^{-6} amp or 1.1 microamperes. Hen
the leakage current is 1.1 × 10^{-6} amperes per mic
farad.

For other capacity sizes formed at 200 volts,
leakage current may be calculated by multiplying 1.1
10^{-6} by the capacity in microfarads.

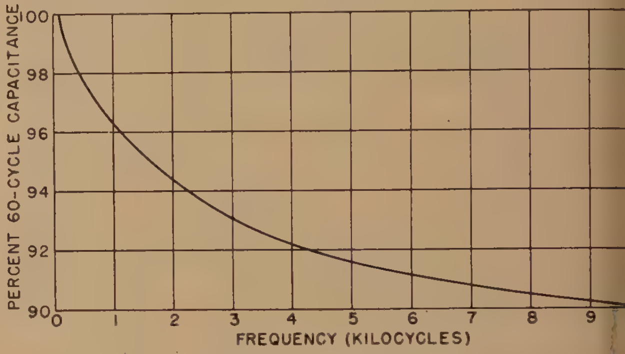


Fig. 14. Percent of 60-cycle capacitance vs. frequency at 25 C

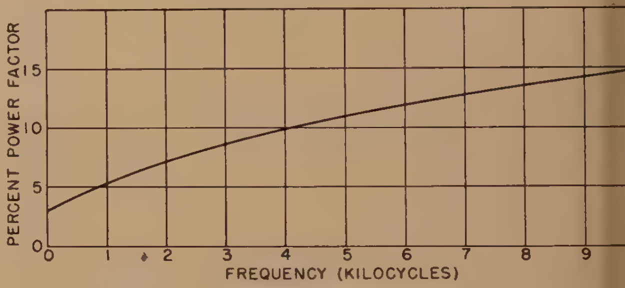


Fig. 15. Power factor vs. frequency at 25 C

Fig. 16. Leakage current vs. time

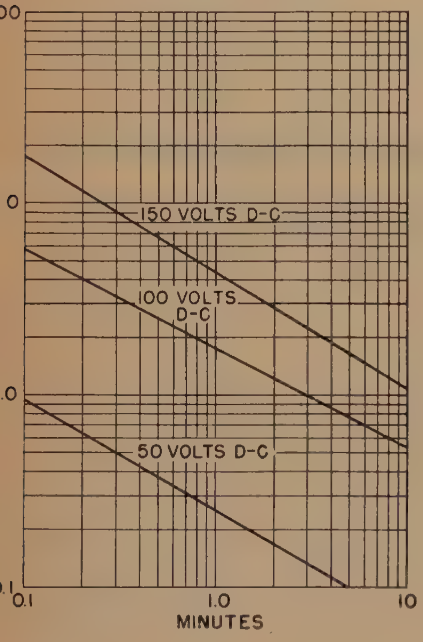


Fig. 17. Resistance times capacitance vs. time

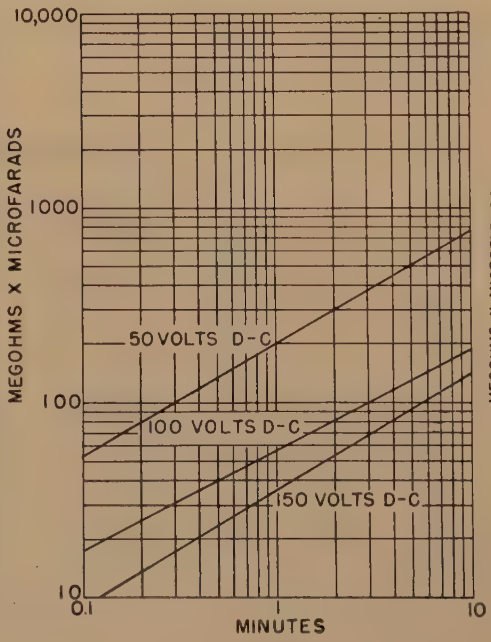
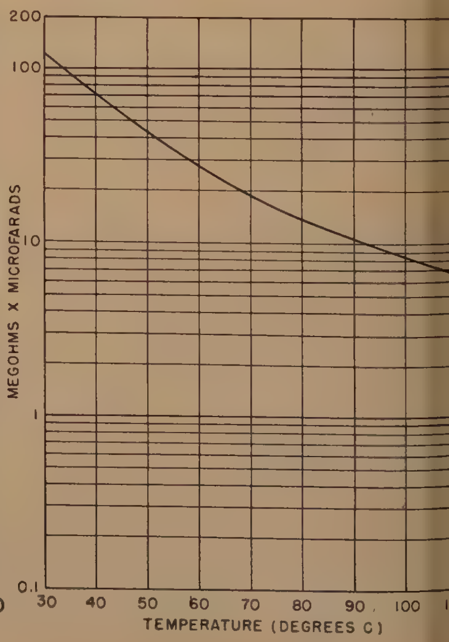


Fig. 18. Megohms × microfarads vs. temp
ture at end of 10 minutes electrification time
a one-microfarad 150 volt d-c polar Tantal
capacitor



lation Resistance vs. Temperature

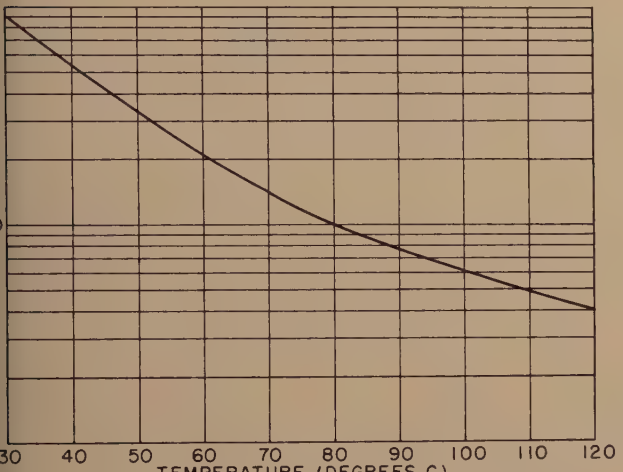
he insulation resistance of a Tantalytic capacitor ne applied voltage divided by the leakage current μf capacitance. This value in megohms × microds, is plotted in Fig. 18 for a range of 30 C to 120 C. values given in Fig. 17 may be corrected for eleed temperatures by use of the curve in Fig. 19 ch gives the reduction in insulation resistance versus perature.

igs. 20 and 21 give typical results for one-microd nonpolar and polar Tantalytic capacitors and plotted for microamperes versus temperature.

es Resistance

he curves in Fig. 22 are estimates from available data and are presented to give a general picture his characteristic. From the series resistance (R_0) values in ohms, the series resistance (R) for various capacity ratings may be estimated by the relation

$$R = \frac{R_0}{\text{microfarads}} \quad \text{ohms}$$



g. 19. Megohms × microfarads in percent of 25 C value at end of minutes electrification time for a one-microfarad 150-volt d-c polar ntalytic capacitor

TABLE III

PERMISSIBLE TEMPERATURE RISE AND WATTS DISSIPATION ON CASE

Ambient Temperature (deg. C)	Case Rise Over Ambient Temperature (deg. C)	Watts per sq in. (W_0) on case
25	30	0.230
35	27	0.185
45	23	0.170
55	19	0.135
65	16	0.108
75	13	0.084
85	10	0.060

The amount of alternating current which may be safely passed by a Tantalytic capacitor can be calculated in the following manner. Case temperature rises over ambient temperatures permissible are given in Table III.

From the series resistance R_0 and current passing through the capacitor, the watts per square inch on a given capacitor case may be calculated as follows:

Example I

Capacitor 29F405 for 10 kc, rated 4μf 150 volts d-c.

Nonpolar—Case size, ⅜ in. diam × 2 in.—Ambient temperature, 75 C. Permissible case rise from Table III is 13 C or 0.084 watts (W_0) per sq in.

Calculate total permissible watts (W):

Area of case = 0.375 × 3.14 × 2.0 = 2.35 sq in.

$W = 0.084 \times 2.35 = I^2R$

$I^2R = 0.197$ watts

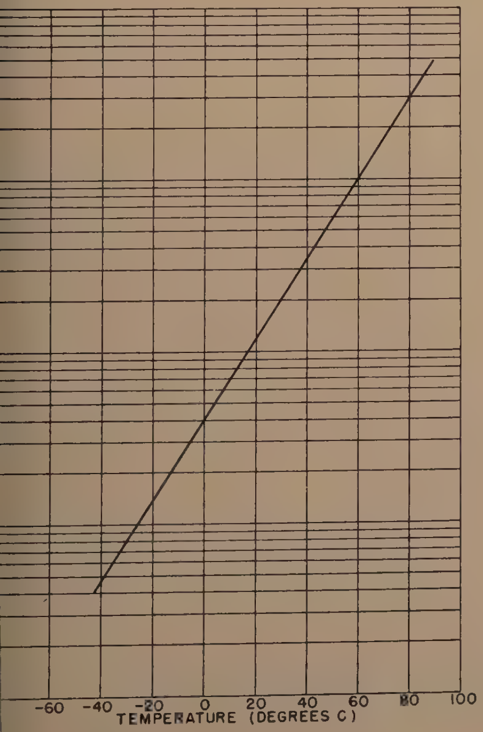


Fig. 20. Leakage current vs. temperature for Tantalytic capacitors rated 10 μf 150 volt d-c nonpolar (tested at 50 volts for one minute)

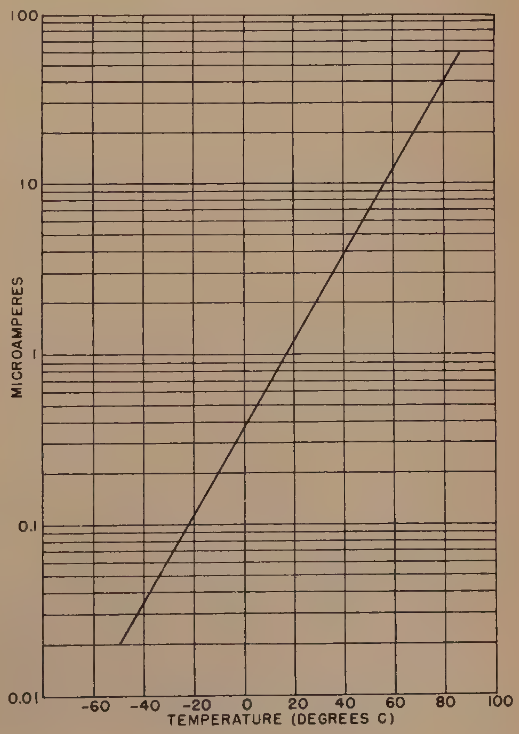


Fig. 21. Leakage current vs. temperature for Tantalytic capacitors rated 10 μf 150 volts d-c polarized (tested at 50 volts for one minute)

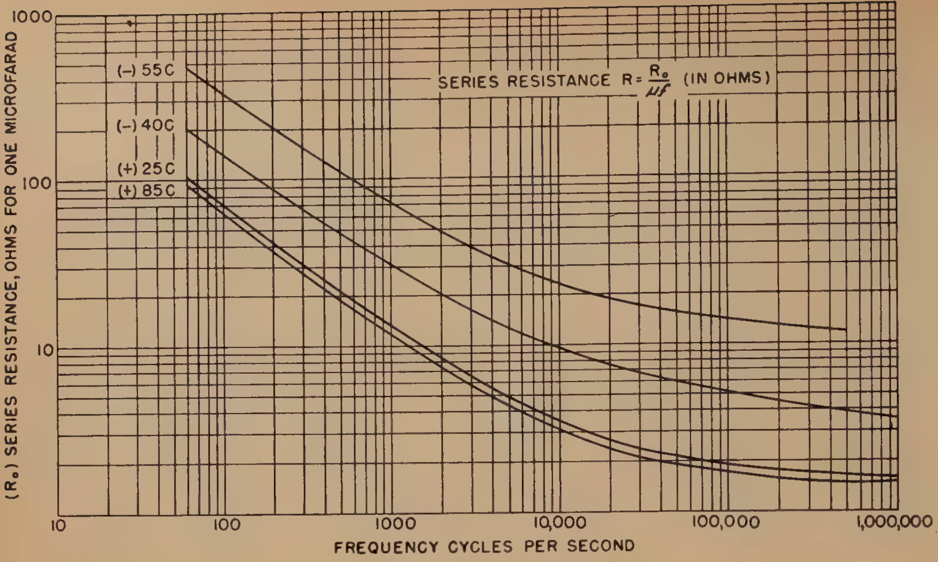


Fig. 22. Curves showing series resista R_0 vs. frequency for various temperatu In applying Tantalytic capacitors, this va of R_0 is divided by the rating in microfar to obtain the series resistance R

Pick value of R_0 from FIG. 22 for 10,000 cycles, 75 C ambient plus 13 C rise or total temperature of 88 C.

$$\text{Thus } R_0=3;\ R=\frac{R_0}{\mu f}=\tfrac{3}{4}=0.75 \text{ ohms}$$

$$I^2=\frac{0.197 \text{ watts}}{0.75 \text{ ohms}}=0.264$$

$$I=0.51 \text{ amp}$$

The a-c voltage across the capacitor is:

$$E=IX_C=I\times\frac{1}{2\pi fC}=\frac{(159{,}500)}{fC}I \text{ (}C\text{ in microfarads;}$$
f in cycles per second)

$$E=\frac{(159{,}500)}{(10{,}000\times 4)}\times 0.51=2.03 \text{ volts}$$

$$I=\frac{E}{X}=\frac{2.03}{4}=0.5 \text{ amp}$$

In general, the heating in Tantalytic capacitors will limit the alternating voltage to a safe value. However, the peak a-c voltage should be subtracted from the d-c rated voltage, as in the case considered here:

$$150 \text{ volts d-c}-2.03\sqrt{2}=147 \text{ volts}$$

Hence, a d-c voltage of 147 volts plus an alternating current of 0.5 amp at 10 kc and 75 C ambient may be applied.

Example II

Another example for the same capacitor is:

25 C ambient; 60 cycles frequency

$R_0=100$ ohms $W_0=0.23$

$X_C=663$ ohms

$I^2R=0.23\times 2.35=0.54$

$$R=\frac{R_0}{4}=25 \text{ ohms}$$

$$I^2=\frac{0.54}{25}=0.0216$$

$I=0.147$ amp

$E=IX_C=0.147\times 663=97.5$ volts RMS at 60 cycles

Crest voltage $=E\sqrt{2}=95.5\sqrt{2}=137$ volts

In this case, the heating limits the 60-cycle current which may be safely carried by the capacitor.

SUMMARY

For many applications the Tantalytic capacitor h proved to be a very valuable tool in the miniaturizati of communication equipment.

Many ratings are now being produced on a quanti production basis and other units will be added as t demand increases.

Sufficient experience in production and testing h been obtained so that reliable application data a available.

Research work is continuing; and under investig tion are a number of developments that offer pos bilities of increased capacitance and voltage, wider te perature ranges, all with longer life and lower cost.

When fully developed, the Tantalytic capacitor h the possibility of replacing the paper capacitor in ma applications on a cost, size, and performance basis; a is also expected to fill the need for a high-grade electr lytic capacitor.

Acknowledgment

While this paper contains much original work, would not have been possible in its entirety witho the wholehearted co-operation of many individuals a organizations. Thanks for their assistance are he given the people in the Signal Corps, the Fanste Metallurgical Corporation, the Bell Telephone La oratories, the General Electric Research Laborato the Capacitor Engineering Division, and the Tra former and Allied Product Laboratory.

References

Electrolytic Condensers, by A. Guntherschulze and Hans Be Verlag Von M. Krayn, Berlin, 1937 (Edwards Bros. Inc., A Arbor, Mich., 1944), pp. 172.

"Miniaturizing the Tantalytic Capacitor," by James H. Hall a Fred H. Berghorn, *Electrical Manufacturing*, Vol. 46, Dec. 19 pp. 82–85.

Tantalum, Fansteel Metallurgical Corp., North Chicago, I Catalog.

"Tantalum As An Engineering Material," by Kenneth Ro *Materials and Methods*, Vol. 26, Oct. 1947, pp. 94–98.

"Tantalum Electrolytic Capacitors," by M. Whitehead, *Laboratories Record*, Vol. 28, Oct. 1950, pp. 448–452.

Unpublished Reports, Signal Corps, Engineering Laboratory

RANSMISSION LOSSES AND ECONOMIC LOADING F POWER SYSTEMS

thods of determining generation schedules d of developing transmission-loss formula d the calculations involved in applying it

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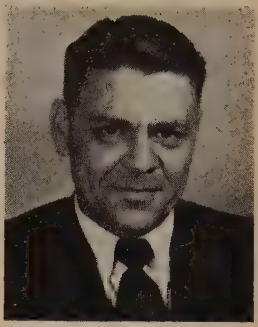

G. H. McDaniel

ONE of the major problems involved in the operation of a power system is the scheduling of genera-n for the most economic system operation. Much rt has been expended in the analysis of fuel costs l the thermal performance of generating units l incremental slide rules have been developed for ding generating units at equal incremental fuel ts.(1) However, with the development of integrated ver systems and the interconnection of operating npanies for purposes of economy interchange, it is essary to consider not only the incremental fuel ts but also the incremental transmission losses for imum economy.

he analysis of incremental transmission losses has n greatly simplified by the development of transsion-loss formulas which express the transmission-tem losses in terms of the plant and interconnection dings.(2),(3) (4) The first part of this article describes ethod of quickly determining generation schedules h both incremental fuel costs and incremental nsmission losses accurately considered; the remaining tion will describe an improved method of obtaining transmission-loss formula and the calculations inved in the application of the loss formula.

DETERMINATION OF GENERATION SCHEDULES

Operation at Equal Incremental Fuel Costs

To define the terms involved, simplified performance curves of a given turbine-generator unit are shown in FIGS. 1 and 2. In FIG. 1, the fuel input in Btu per hour is plotted as a function of plant output in megawatts. The incremental fuel-rate curve in FIG. 2 is a plot of the slope of the fuel-input curve in FIG. 1. The incremental fuel rate is converted to incremental fuel cost by multiplying the incremental fuel rate in Btu per kilowatt-hour by the fuel cost in cents per million Btu. The incremental fuel cost is usually expressed in mills per kilowatt-hour.

If all generating units are assumed to be at the same bus, it is known that minimum fuel input in dollars per hour for a given total load is obtained when all generating units are operated at the same incremental fuel cost.(1) The scheduling of generation for operation at equal incremental costs can be efficiently accomplished through the use of an incremental fuel-rate slide rule. FIG. 3 schematically illustrates the incremental fuel-rate slide rule for a two-generator system.

Essentially, this slide rule consists of a logarithmic calibration scale, a movable strip for each generator

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)Numbered references are listed at the end of the article.

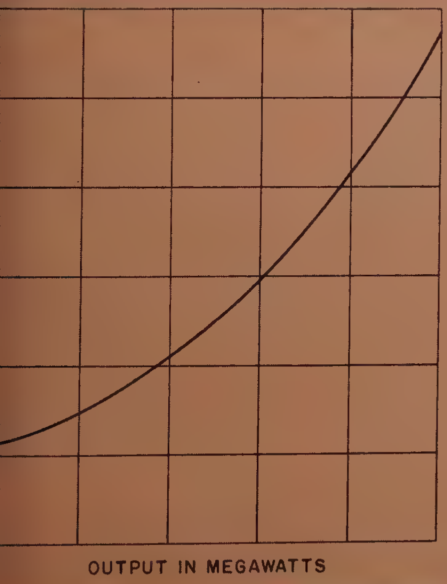


Fig. 1. Simplified performance curve showing fuel input of a turbine-generator unit

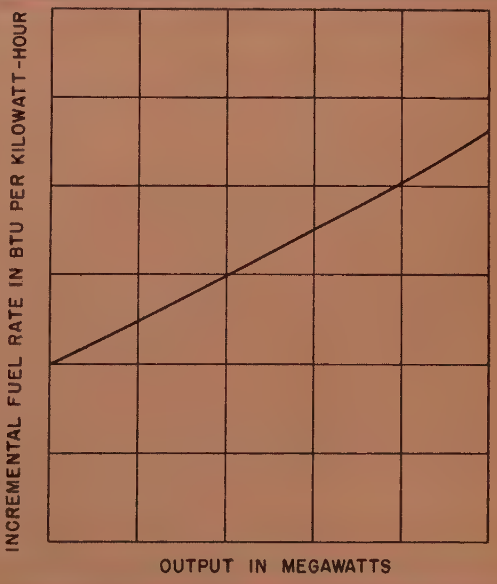


Fig. 2. Simplified performance curve of a turbine-generator unit showing the incremental fuel rate, which is the slope of the fuel-input curve in Fig. 1

unit, and a fuel-cost adjustment scale. The calibration scale is graduated in Btu per kilowatt-hour to a logarithmic scale. Each movable generator strip is calibrated in megawatts and indicates the relation between the incremental fuel rate and output of a given generator unit. Differences in fuel costs can be accounted for by displacing a given generator strip so as to line up the bottom of the strip to a position on the fuel-cost adjustment scale corresponding to the ratio of the fuel costs. For a given incremental fuel cost, corresponding generator outputs can then be read directly from the strips. If the fuel costs for both generators are assumed equal, it is seen in Fig. 3 that, for a total load of 250 megawatts, 150 megawatts should be scheduled from Generator 1; and 100 megawatts from Generator 2.

Co-ordination of Incremental Fuel Costs and Incremental Transmission Losses

If the criterion of equal incremental fuel costs is applied to a power system in which all generators are not at the same bus, it will be found that there will be

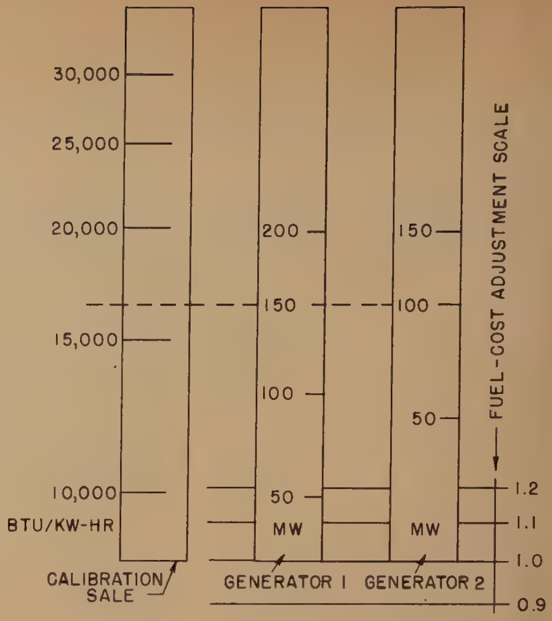
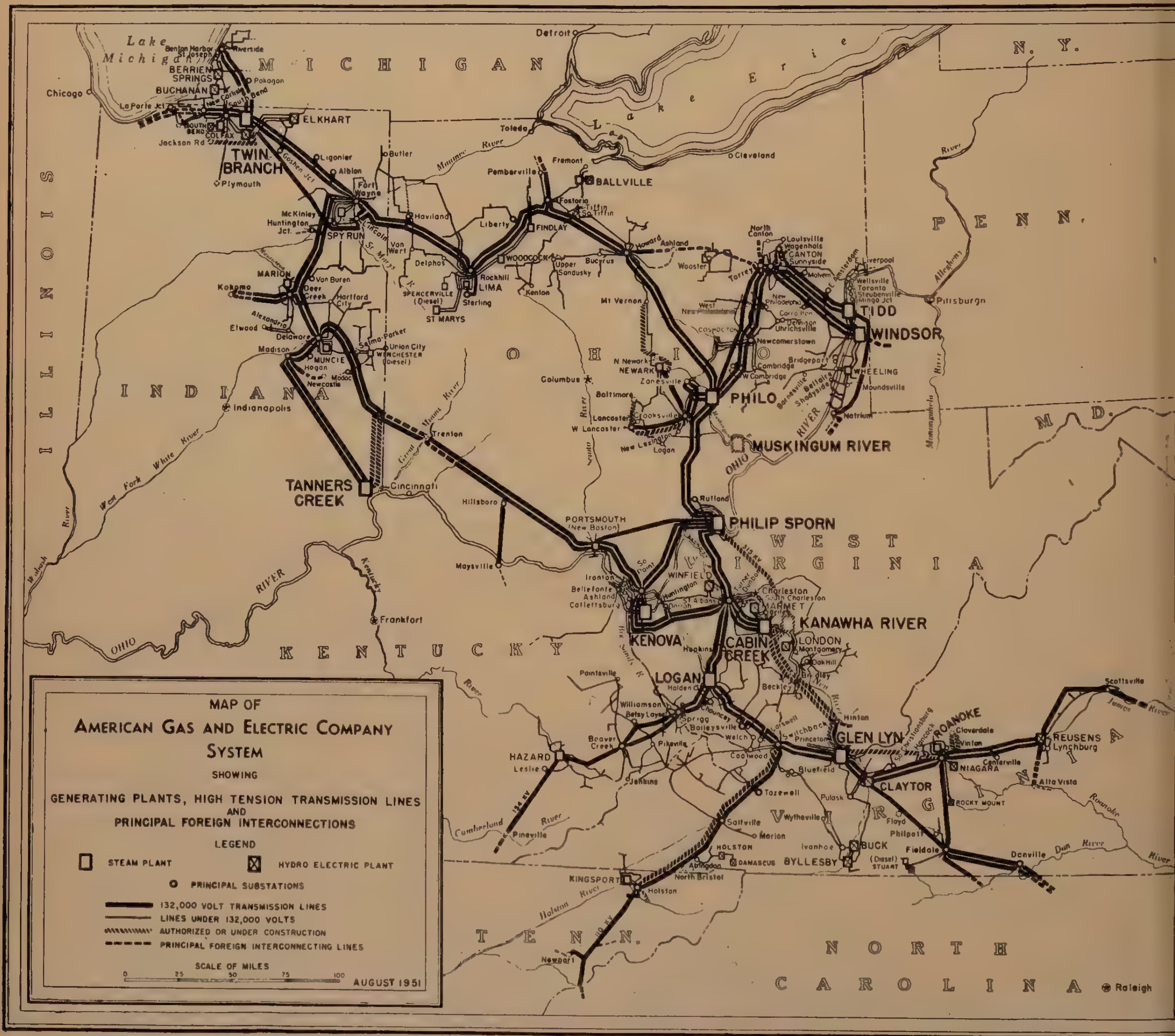


Fig. 3. Schematic diagram of the incremental fuel-rate slide rule for a two-generator system

Fig. 4. Map showing the power system of the American Gas and Electric Co.



ısmission of power from low-cost areas to high-cost as. It is necessary for optimum economic system ration to recognize that transmission-line losses ur in this operation and to modify the incremental l costs of all plants to take these line losses into ac- nt. To do this, it is required to apply factors cal- ıted from studies of incremental line losses for the ire system to the incremental fuel costs of all nts. These factors are treated as penalty factors to incremental fuel cost of all generating plants.

he penalty factor for a given plant can be expressed means of a transmission-loss formula involving the gawatt loading of all steam plants, hydro plants, ercónnections, and by a set of constants. These con- ıts, which are denoted by B_{nm}, are obtained from network-analyzer data and calculations as de- bed later.

hese penalty factors can be applied to the incre- ntal fuel-rate slide rule by the use of penalty-factor les or charts covering the conditions existing on the tem at a given time. For the American Gas and ctric System (FIG. 4), which consists of the Ohio, iana, and Appalachian operating divisions, charts ilar to FIG. 5 have been prepared. However, for of operation, computers are being considered to ordinate incremental fuel costs and incremental ısmission losses.

cedure in Obtaining Generation Schedules

he method involved in the actual hour-by-hour nomic scheduling of generation is:

(1). Obtain a trial generation schedule, neglect- ng transmission losses, from the incremental fuel- ate slide rule

(2). With the generation schedule from (1), etermine penalty factors for all steam plants from he tables or charts

(3). Displace the incremental fuel-rate strip of a iven plant by the logarithm of the penalty factor. Determine a new generation schedule from incre- ıental fuel-rate slide rule

(4). With the generation schedule determined rom (3), determine new penalty factors from the ables or charts as above

(5). Using the new penalty factors from (4) on he incremental slide rule, determine a new genera- ion schedule.

s rapidly converging cycle of calculation is repeated il the penalty factors used on the slide rule correspond he generation schedule obtained from the slide rule. n the course of calculating the daily load schedule, not necessary to start with step (1) each time. The al procedure would be to obtain an initial genera- schedule from the incremental fuel-rate slide rule ıg the penalty factors corresponding to the genera- schedule of the preceding hour, and then use this ial generation schedule in step (4).

his procedure converges quickly to the correct tion primarily for these reasons:

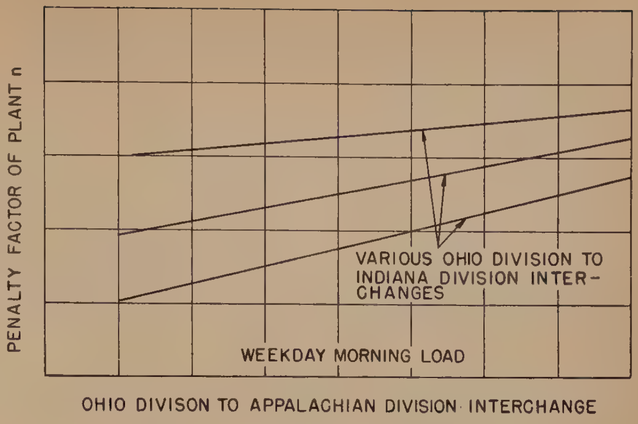


Fig. 5. Curves showing penalty factors

(1). The penalty factors are corrections on the incremental fuel costs with the incremental fuel costs generally being the most important factor in determining allocation of generation

(2). Also, in determining generation schedules on an hour-to-hour basis, only small changes in generation are involved with correspondingly much smaller changes in penalty factors.

Application of Method

The steps involved in the analysis of the economic operation of a given system are outlined as follows:

(1). Preparation of data

The data required are:

(a). Impedance diagram of transmission and subtransmission facilities whose losses are dependent upon manner in which generation is scheduled

(b). Daily load cycles for typical week's operation

(c). Selection of base-case loading periods of most importance from the standpoint of economy loading and tabulation of loads, voltages, and probable generation schedules and interconnection flows for base cases

(d). Incremental fuel-cost data for generating units(1)

(2). Determination of loss formula

(3). Evaluation of savings

(4). Preparation of tables or charts of penalty factors.

The calculations involved in (2), (3), and (4) in the outline just given will be explained later.

TRANSMISSION-LOSS FORMULA AND CALCULATIONS

Determination of Transmission-loss Formula

The method involved in the determination of a transmission-loss formula will be illustrated by application to the simple three-generator problem given in FIG. 6. All the required network-analyzer data and calculations are shown in detail to assist in understanding the procedure. A theoretical development of this method,

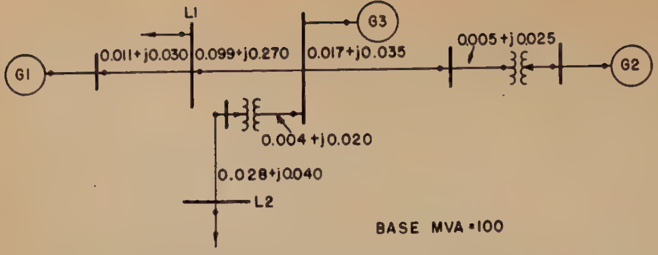


Fig. 6. Impedance diagram for determining a transmission loss formula as applied to a simple three-generator problem

together with a numerical evaluation of the assumptions involved, has been presented.(3),(4) Briefly, these assumptions are:

(1). All load currents vary together

(2). The generator terminal voltages are of constant absolute value

(3). The ratio of reactive to real power of a given generator remains at a fixed value

(4). The generator terminal voltages remain at fixed angles.

It has been found that a loss formula derived with these assumptions closely approximates the losses in a power system over a wide range of operating conditions. In general, the total transmission losses are given by

$$P_{\text{Losses}} = \text{Total transmission losses}$$

$$= \sum_m \sum_n P_m B_{nm} P_n \tag{1}$$

where P_m, P_n = Real power output of Generators m and n

B_{nm} = Constants to be determined

Also, the incremental transmission loss at Generator n is given by

$$\frac{\partial P_{\text{Losses}}}{\partial P_n} = \sum_m 2B_{nm} P_m \tag{2}$$

For the three-generator problem under consideration,

$$P_{\text{Losses}} = B_{11}P_1^2 + B_{22}P_2^2 + B_{33}P_3^2 + 2B_{12}P_1P_2 + 2B_{13}P_1P_3 + 2B_{23}P_2P_3$$

Also, the incremental transmission losses at Generators *1*, *2*, and *3* are given by

$$\frac{\partial P_{\text{Losses}}}{\partial P_1} = 2B_{11}P_1 + 2B_{12}P_2 + 2B_{13}P_3$$

$$\frac{\partial P_{\text{Losses}}}{\partial P_2} = 2B_{12}P_1 + 2B_{22}P_2 + 2B_{23}P_3$$

$$\frac{\partial P_{\text{Losses}}}{\partial P_3} = 2B_{13}P_1 + 2B_{23}P_2 + 2B_{33}P_3$$

Network Analyzer Measurements Required

In the following analysis, the word generator is understood to be either a steam generator, hydro generator, interconnection, or load that is to be included in the loss formula. A load that does not vary in the same manner as the remaining loads may be included explicitly in the loss formula. Because the constant the loss formula are dependent upon the load patte generator bus voltages, angles, and power factor, i desirable to obtain loss formulas from two base co tions and use the average of these two loss formu in the study of transmission losses.

Load-flow Study

(1). Record generator voltage magnitudes, me watts, megavars, and angles (Fig. 7)

(2). Record scalar values of all line curre (Fig. 8)

(3). With the network-analyzer reference cho such that the summation of the currents of the g erators included in the loss formula equals a r number, record all generator vector currents and real parts of all equivalent load currents (Fig. The equivalent load current at a bus is defined to the sum of the synchronous condenser, line-chargi and load current at that bus

(4). For a check on the system operation, i desirable to record load voltages, load and line me watts and megavars, and synchronous-conden megavars.

Impedance Measurements

(1). Remove from ground all line-charging cap itors, synchronous condensers, loads, and generat

(2). Ground the reference point. It is best choose one of the major plants as the reference po which, in this case, is *G1*

(3). Impress a known current i_{Gm} at a given g erator m and read the real part of the voltage at generator buses and loads with impressed curr as reference. Also, read the real part of the curr flowing through the reference point i_{Rm}.

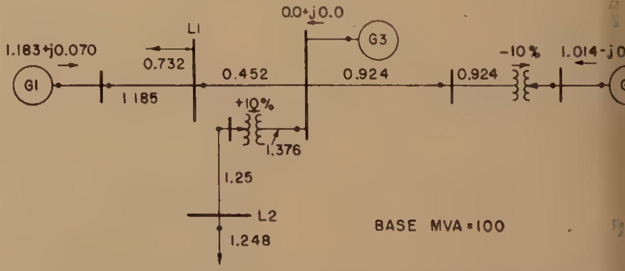


Fig. 7. Schematic diagram giving normal load-flow data

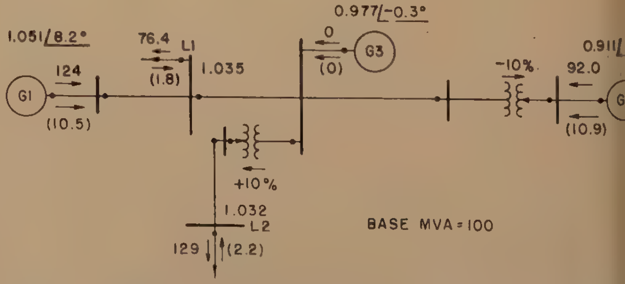


Fig. 8. Schematic diagram for generator, load, and scalar line curre

his test is indicated schematically in FIG. 9 and
cifically in FIGS. 10 and 11 with $G2$ and $G3$ respec-
ly energized.

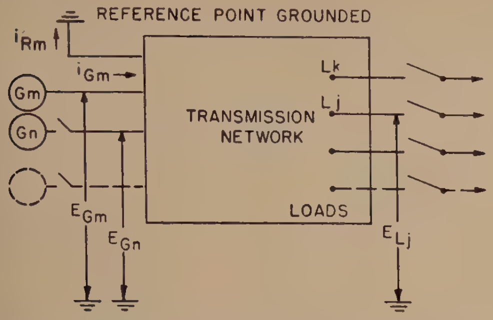
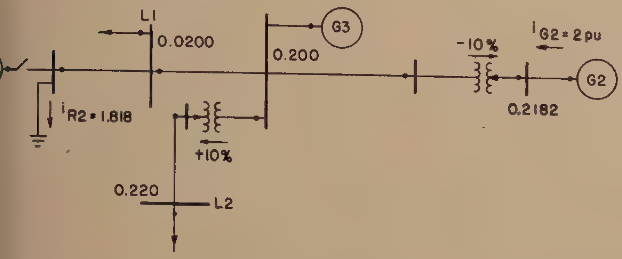


Fig. 9. Schematic diagram of impedance measurement of $R_{Gn\text{-}Gm}$ and $R_{Lj\text{-}Gm}$



g. 10. Schematic diagram showing measurement of $R_{Gn\text{-}G2}$ and $R_{Lj\text{-}G2}$

FIG. 9,

$R_{Gn\text{-}Gm} = R_{Gm\text{-}Gn}$ = Measured resistance between Generator n and Generator m

$$= \text{Real part of } \frac{E_{Gn}}{i_{Gm}} \tag{3}$$

$R_{Lj\text{-}Gm} = R_{Gm\text{-}Lj}$ = Measured resistance between Generator m and load j

$$= \text{Real part of } \frac{E_{Lj}}{i_{Gm}} \tag{4}$$

$$K_m = \text{Real part of } \frac{i_{Rm}}{i_{Gm}} \tag{5}$$

here are no autotransformers, $K_m = 1$

example, in FIG. 10,

$$R_{Gn\text{-}G2} = \text{Real part of } \frac{E_{Gn}}{i_{G2}}$$

$$R_{G1\text{-}G2} = \frac{0}{2.0} = 0$$

$$R_{G2\text{-}G2} = \frac{0.2182}{2} = 0.1091$$

$$R_{G3\text{-}G2} = \frac{0.2000}{2} = 0.1000$$

o,

$$R_{Lj\text{-}G2} = \text{Real part of } \frac{E_{Lj}}{i_{G2}}$$

$$R_{L1\text{-}G2} = \frac{0.0200}{2} = 0.0100$$

$$R_{L2\text{-}G2} = \frac{0.2200}{2} = 0.1100$$

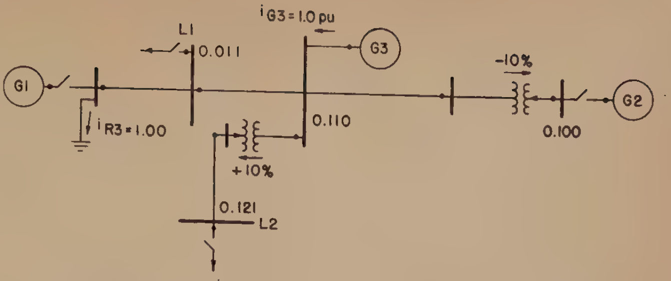


Fig. 11. Schematic diagram showing measurement of $R_{Gn\text{-}G3}$ and $R_{Lj\text{-}G3}$

These values correspond to the resistances shown in the second columns of Tables I and II which are respectively the $R_{Gn\text{-}Gm}$ matrix and the $R_{Lj\text{-}Gm}$ matrix. The K_m matrix is given in Table III.

TABLE I

MEASURED $R_{Gn\text{-}Gm}$ RESISTANCES

n ↓ \ m →	G1	G2	G3
G1	0.0	0.0	0.0
G2	0.0	0.1091	0.1000
G3	0.0	0.1000	0.1100

TABLE II

MEASURED $R_{Lj\text{-}Gm}$ RESISTANCES

j ↓ \ m →	G1	G2	G3
L1	0.0	0.0100	0.0110
L2	0.0	0.1100	0.1210

TABLE III

CALCULATED K_m

m → 1	2	3
1.00	0.909	1.00

Calculation of B_{nm}

The B_{nm} are calculated in the following manner:

(1). Calculate

$$d_m = \frac{1}{i_L} \sum_j i_{Lj} R_{Lj\text{-}Gm} \tag{6}$$

where $i_L = \sum_j i_{Lj}$ = Total load current

i_{Lj} = Real part of equivalent load current from base case

$R_{Lj\text{-}Gm}$ = Measured resistance between generator m and load j, as given in Table II.

TABLE IV

CALCULATION OF d_m

	i_{Lj}	$R_{Lj\text{-}G1}$	$i_{Lj}R_{Lj\text{-}G1}$	$R_{Lj\text{-}G2}$	$i_{Lj}R_{Lj\text{-}G2}$	$R_{Lj\text{-}G3}$	$i_{Lj}R_{Lj\text{-}G3}$
L1	0.732	0.0	0.0	0.0100	0.00732	0.0110	0.00805
L2	1.248	0.0	0.0	0.1100	0.13730	0.1210	0.1510

$i_L=\sum_j i_{Lj}=1.98$ $\qquad \sum_j i_{Lj}R_{Lj\text{-}G1}=0.0$ $\qquad \sum_j i_{Lj}R_{Lj\text{-}G2}=0.1446$ $\qquad \sum_j i_{Lj}R_{Lj\text{-}G3}=0.1591$

$d_1=0.0$

$$d_2=\frac{0.1446}{1.98}=0.0730$$

$$d_3=\frac{0.1591}{1.98}=0.0804$$

TABLE V

d_m MATRIX

$m \longrightarrow$ 1	2	3
0.0	0.0730	0.0804

The calculation of d_m is given in Table IV. The d_m matrix obtained is given in Table V.

(2). Define D_R = Total real current flowing through reference generator when all the load currents are supplied from reference generator.

Then

$$D_R=\sum_m K_m\,(i_{dm}) \qquad (7)$$

TABLE VI

$[R_{Gn\text{-}Gm}-C_md_n-C_nd_m]$ MATRIX

$n \downarrow$ \ $m \longrightarrow$	1	2	3
1	0.0	−0.06886	−0.07562
2		−0.01570	−0.03741
3			−0.0412

This matrix is symmetrical

where

i_{dm} = Real part of Generator m current in base case

From FIG. 8 and Table III,

$$\begin{aligned}D_R&=1.0(1.183)+0.909(1.014)+1.0(0.0)\\&=1.183+0.9217\\&=2.105\end{aligned}$$

Define

$$C_m=K_m\frac{i_L}{D_R}=K_m\left(\frac{1.98}{2.105}\right) \qquad (8)$$

$$=K_m(0.9406)$$

Then

$$\begin{aligned}C_1&=0.9406\\C_2&=(0.9406)\ (0.909)=0.8550\\C_3&=0.9406\end{aligned}$$

When there are no autotransformers in the network, C_m is identically unity for all n.

Calculate

$$R_{n\text{-}m}-C_nC_mw'=R_{Gn\text{-}Gm}-C_md_n-C_nd_m$$

For example,

$$\begin{aligned}R_{2\text{-}3}-C_2C_3w'&=R_{G2\text{-}G3}-C_3d_2-C_2d_3\\&=0.10-0.9406(0.0730)-\\&\quad 0.8550(0.0804)\\&=0.1000-0.06866-0.06875\\&=-0.03741\end{aligned}$$

The values of $R_{Gn\text{-}Gm}-C_md_n-C_nd_m$ are given Table VI.

(3). Calculate w' from the relationship

$$w'=\frac{\sum_k i_k^2R_k-\sum_m\sum_n(i_{dm}i_{dn}+i_{qm}i_{qn})(R_{Gn\text{-}Gm}-C_md_n-C_nd_m)}{\sum_m\sum_n(i_{dm}i_{dn}+i_{qm}i_{qn})C_mC_n}=+0.0730$$

where

R_k = Resistance of Line k

i_k = Scalar current in Line k from base ca

$\sum_k i_k^2R_k$ = Total transmission losses of base ca

i_{dm} = Real component of Generator m curre from base case

i_{qm} = Imaginary component of Generator current from base case

This calculation is given in Table VII.

(4). Calculate

$$R_{n\text{-}m}=R_{Gn\text{-}Gm}-C_md_n-C_nd_m+C_nC_mw' \qquad (1$$

Thus

$$\begin{aligned}R_{2\text{-}3}&=R_{G2\text{-}G3}-C_3d_2-C_2d_3+C_2C_3w'=R_{2\text{-}3}-C_2C_3w'\\&\quad C_2C_3w'\\&=-0.03741+(0.8550)\ (0.9406)\ (0.0730)\\&=-0.03741+0.05871\\&=+0.02130\end{aligned}$$

The values of $R_{n\text{-}m}$ are given in Table VIII.

(5). Calculate

$$B_{mn}=B_{nm}=\frac{1}{V_mV_n}\left\{(1+s_ms_n)\cos\theta_{mn}+(s_m-s_n)\sin\theta_{mn}\right\}R_{n\text{-}m} \qquad ($$

TABLE VII

CALCULATION OF w'

m	n	C_mC_n	$i_{dm}i_{dn}$	$i_{qm}i_{qn}$	$(i_{dm}i_{dn}+i_{qm}i_{qn})$	$C_mC_n(i_{dm}i_{dn}+i_{qm}i_{qn})$	$(R_{Gn\text{-}Gm}-C_md_n-C_nd_m)$	$(i_{dm}i_{dn}+i_{qm}i_{qn})(R_{Gn\text{-}Gm}-C_md_n-C_nd_m)$
1	1	0.8847	1.399	0.0049	1.404	1.242	0.000	0.00000
2	2	0.7310	1.028	0.0049	1.033	0.7551	−0.0157	−0.01622
3	3	0.8847	0.000	0.0000	0.000	0.0000	−0.0412	0.00000
						1.997		−0.01622
1	2	0.8042	1.200	−0.0049	1.195	0.9610	−0.06866	−0.08205
1	3	0.8847	0.000	0.0000	0.000	0.0000	−0.07562	0.00000
2	3	0.8042	0.000	0.0000	0.000	0.0000	−0.03741	0.00000
						0.9610		−0.08205

$$\sum_{n}(i_{dm}i_{dn}+i_{qm}i_{qn})(R_{Gn\text{-}Gm}-C_md_n-d_nC_n)=0.01622-2(0.08205)$$
$$=-0.01622-(0.1641)=-0.1803$$

$$\sum_{m}\sum_{n}(i_{dm}i_{dn}+i_{qm}i_{qn})=1.997+2(0.9610)$$
$$=1.997+1.922=3.919$$

om base case,

$$P_{\text{Losses}}=\sum_k i_k^2R_k=0.1058$$

en

$$w'=\frac{\sum_k i_k^2R_k-\sum_m\sum_n(i_{dm}i_{dn}+i_{qm}i_{qn})(R_{Gn\text{-}Gm}-C_md_n-C_nd_m)}{\sum_m\sum_n(i_{dm}i_{dn}+i_{qm}i_{qn})C_mC_n}=\frac{0.1058+0.1803}{3.919}=\frac{0.2861}{3.919}=0.0730$$

TABLE VIII

$R_{n\text{-}m}$ MATRIX

$n\downarrow$ \ $m\rightarrow$	1	2	3
1	0.06458	−0.00995	−0.01104
2		+0.03767	+0.02130
3			+0.02338

This matrix is symmetrical

V_m = Bus voltage of Generator m

θ_m = Angular position of terminal voltage of Generator m

Q_m = Reactive power output of Generator m

$s_m=\dfrac{Q_m}{P_m}$ of Generator m for base case

From FIG. 7 the following data can be tabulated:

Gen. No.	P_m	Q_m	s_m	V_m	θ_m
1	124	10.5	0.084	1.051	8.2
2	92	10.9	0.12	0.911	2.8
3	000	00.0	0.00	0.977	-0.3

TABLE IX

TABULATION OF B_{nm}

$B_{11}=0.0589$
$B_{22}=0.0460$
$B_{33}=0.0245$
$B_{12}=-0.0104$
$B_{13}=-0.0108$
$B_{23}=+0.0241$

The value of $\dfrac{Q_m}{P_m}$ for Generator 3 is assumed to be zero.

Thus

$$B_{22}=\frac{1}{V_2^2}(1+s_2^2)\,R_{2\text{-}2}$$

$$B_{22}=\frac{1}{(0.911)^2}(1+0.12^2)\ (0.03767)$$

$$=0.04604$$

$$B_{23}=\frac{1}{V_2V_3}\left\{(1+s_2s_3)\cos\theta_{23}+(s_2-s_3)\sin\theta_{23}\right\}R_{2\text{-}3}$$

$$=\frac{1}{(0.911)\ (0.977)}\Big\{[1+(0)\ (0.12)]\cos 3.1°+$$
$$[(0.12)\sin 3.1°)]\Big\}(0.0213)$$

$$=0.0241$$

The values of B_{nm} are given in Table IX.

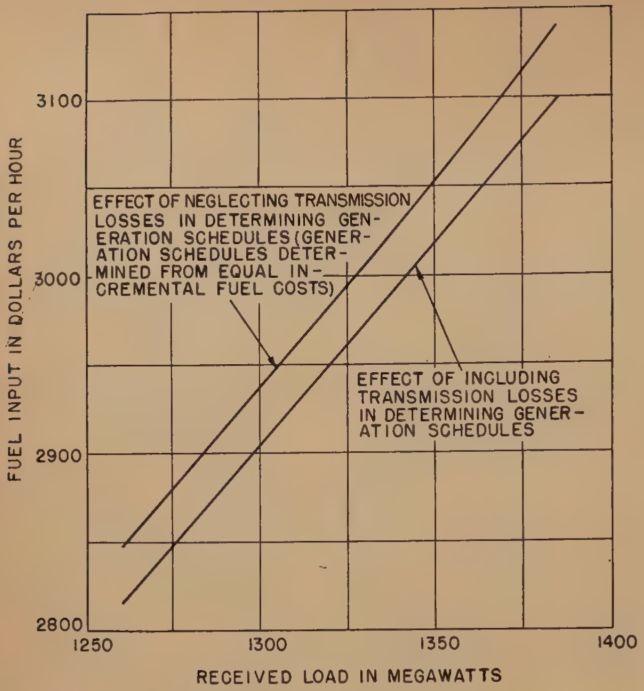


Fig. 12. Curves of fuel input vs. received load as an evaluation of savings

(6). The B_{nm} can be checked by calculating the losses for the base case. Thus, since $P_3=0$

$$P_{\text{Losses}}=B_{11}P_1^2+B_{22}P_2^2+2B_{12}P_1P_2$$

Substituting the per unit values of P_1 and P_2 into this equation gives

$$P_{\text{Losses}}=0.106 \text{ per unit}$$

This checks the losses of 0.106 obtained by summing the I^2R losses in each line from the base case.

Evaluation of Savings

It is prudent to evaluate the savings involved when scheduling generation with the effect of incremental transmission losses, using typical fuel-cost data and typical operating conditions.

It is suggested that this step be taken before preparing the tables of penalty factors to determine whether the preparation of tables of penalty factors is justifiable. For this purpose, it is sufficient to use one of the previously published methods(5) for co-ordinating incremental fuel costs and incremental transmission losses. In general, the simultaneous equations described(5) can be solved to better advantage on digital computers than on the a-c network analyzer.

The steps involved in this evaluation of savings for typical operating conditions are:

(1). Determine a generation schedule by operating the plants at equal incremental fuel costs

(2). Determine a generation schedule including the effect of incremental transmission losses by solving the proposed simultaneous equations(5) by means of IBM punched-card machines.(6),(7),(8)

(3). Calculate the fuel inputs for the generation schedules

(4). Calculate the total transmission losses cor sponding to the generation schedules

(5). Plot curves of fuel input as a function of ceived load, as in FIG. 12.

It is interesting to note that an average saving of dollars per hour corresponds to an annual saving 175,000 dollars.

Preparation of Charts or Tables

The penalty factor L_n for a given plant n may expressed in terms of the megawatt loading of all ste plants, hydro plants, and interconnections in t manner:

L_n = Penalty factor of plant n
= 1 + incremental transmission loss of plant n
$= 1+\sum_m 2B_{nm}P_m$

where
P_m = Plant or interconnection megawatt loadi
B_{nm} = Constants of transmission-loss formula

Optimum economy is obtained when:

(Incremental fuel cost of Plant *1*) $(L_1)=C$
(Incremental fuel cost of Plant *2*) $(L_2)=C$
. . . .
(Incremental fuel cost of Plant n) $(L_n)=C$

where C = Incremental cost of received power.

The penalty factors for numerous operating con tions of the system can be efficiently calculated means of digital computers.

Other Applications of Loss Formula

Frequently, it is important to know the change transmission losses in a company under different c ditions of sales and purchases to and from neighbor companies for purposes of billing. These changes total system losses may be easily evaluated by me of a total system-loss formula in which the vari external interconnections are included as specif variables.

References

(1)*Economy Loading of Power Plants and Electric Systems:* M Steinberg and T. H. Smith, John Wiley and Sons, Inc., New Y 1943.

(2)"Total and Incremental Losses in Power Transmission N works," by J. B. Ward, J. R. Eaton, and H. W. Hale, A Technical Paper 50–97.

(3)"Tensorial Analysis of Integrated Transmission System Part I: The Six Basic Reference Frames," by G. Kron, A Technical Paper 51–225.

(4)"Analysis of Total and Incremental Losses in Transmis Systems," by L. K. Kirchmayer and G. W. Stagg, AIEE T nical Paper 51–204.

(5)"Co-ordination of Fuel Cost and Transmission Loss by of the Network Analyzer to Determine Plant Loading Schedul by E. E. George, H. W. Page, and J. B. Ward, *AIEE Transacti* vol. 68, Part II, 1949, p. 1152.

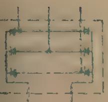
(6)*High-Speed Computing Devices:* Staff of Engineering Rese Associates, Inc., McGraw Hill Book Company, Inc., New Y 1950, Chapter IX.

(7)"Punched Card Techniques for the Solution of Simultan Equations and Other Matrix Operations," by W. D. Beck, *ceeding of Scientific Computation Forum,* International Busi Machines, New York, 1948.

(8)"The Solution of Simultaneous Linear Equations with Aid of the 602 Calculating Punch," by F. Verzuh, *Mathema Tables and Other Aids to Computation*, No. 27, July, 1949.

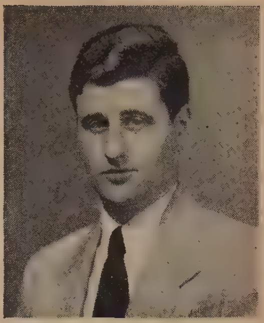
ELENIUM RECTIFIERS FOR ELEVATOR POWER SUPPLY

Meeting the growing need for a convenient, economical solution to the conversion of power for elevator motors



By P. V. HAHN

Lighting and Rectifier Department
General Electric Company



Peter V. Hahn

APPLICATION of selenium rectifiers as a source of power for d-c elevator motors has assumed a new portance, because of the present trend toward placing d-c power feeders with the more economical c distribution system. The experience of many ctric-power companies and building managements s proved this application to be efficient, convenient, xpensive, and dependable.

Because the rectifier is located between the a-c stem and the d-c motor, no changes have to be made the elevator equipment. Local building codes some-nes specify that complete renovation of the elevator stallation must be made if any portion of it is altered. such instances, with the use of a conversion unit this type, no renovations are necessary, the installed uipment is utilized, and a reliable power supply the elevator drive is obtained.

mponents of the Unit

A typical unit for this application, shown in Fig. 1, nsists of an insulated transformer, selenium-rectifier acks, a cooling fan, and auxiliary control equipment. nese elements are enclosed in a metal casing. A fused c disconnect switch, equipped with fuses of high terrupting capacity, and a 3-pole a-c contactor with ermal-overload protection control the input power to the delta-wye transformer (Fig. 2). This transformer is equipped with taps to allow for 10 percent line-voltage variation as well as the eventual aging characteristic of selenium rectifiers. The taps are adjusted on the

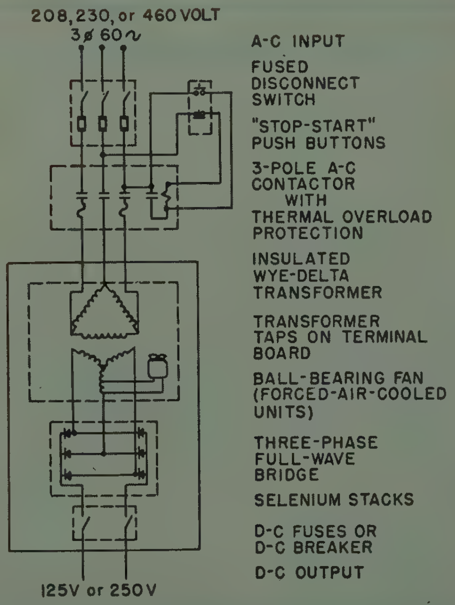
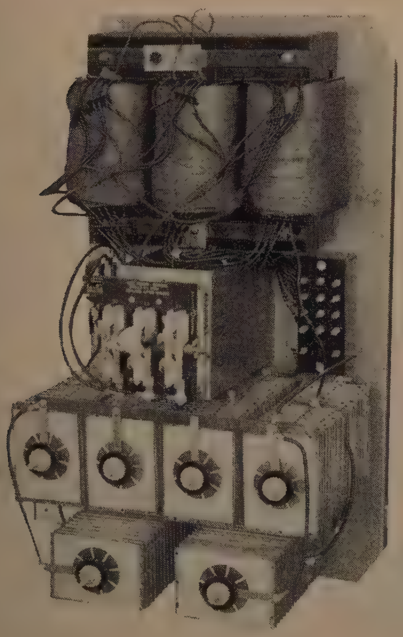

208, 230, or 460 VOLT
3ø 60∿
A-C INPUT
FUSED DISCONNECT SWITCH
"STOP-START" PUSH BUTTONS
3-POLE A-C CONTACTOR WITH THERMAL OVERLOAD PROTECTION
INSULATED WYE-DELTA TRANSFORMER
TRANSFORMER TAPS ON TERMINAL BOARD
BALL-BEARING FAN (FORCED-AIR-COOLED UNITS)
THREE-PHASE FULL-WAVE BRIDGE
SELENIUM STACKS
D-C FUSES OR D-C BREAKER
D-C OUTPUT
125V or 250V

Fig. 2. Schematic diagram of a selenium-rectifier unit as used for d-c elevator drives



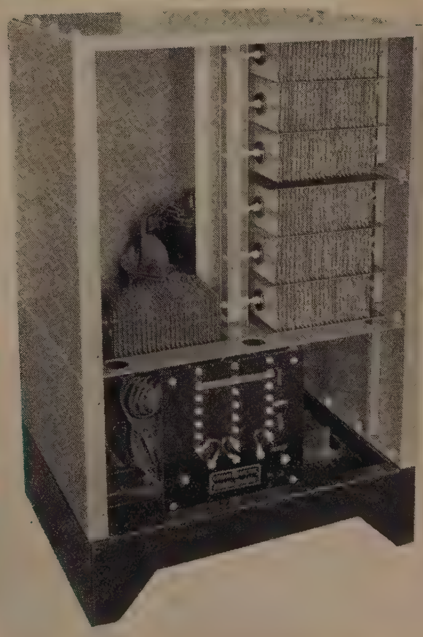


Fig. 1. Typical selenium rectifiers (partly assembled) used for driving d-c elevator motors: *left,* 5-kw, for wall mounting; *right,* 15- to 25-kw

easily accessible terminal board, and the correct a-c power is supplied to the selenium stacks to provide the required d-c output voltage for the load.

The selenium-rectifier stacks are arranged to form a 3-phase, full-wave bridge-type circuit, thereby providing the d-c power required to operate the elevator motor. On the d-c side, fuses or a fused disconnect switch serve to disconnect the unit from the line.

The equipment is housed in a casing made of two or more standardized vertical sections bolted together, one on top of another. Casings can be built in exactly the right size for the required rating. The transformer and terminal board are mounted in the bottom section. The selenium-rectifier stacks are installed on a vertical rack near the front of the unit.

A fan provides cooling of the selenium stacks and of the transformer on all forced-air-cooled ratings. Air is taken in through the front wire-mesh panel, blown across the selenium stacks and down across the transformer (Fig. 3). Thus no dirt or dust is sucked up from the floor of the factory.

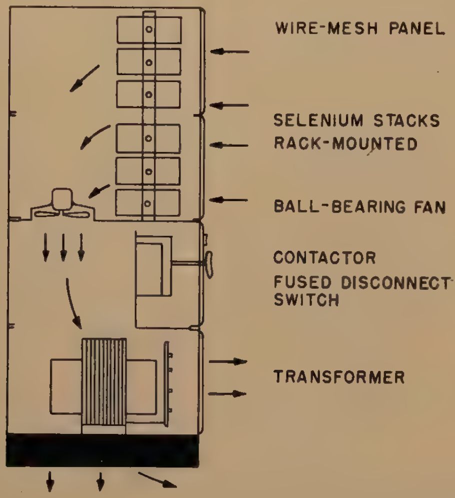


Fig. 3. Block diagram showing air flow for cooling selenium stacks and transformers in a typical ac/dc conversion unit

Present trends indicate that a-c power is distributed by a 3-phase 60-cycle a-c system, at 208, 230, or 460 volts. Ratings of output required vary with the size of the elevator. D-c output voltages of 125 volts and 250 volts d-c are standard; occasionally 500 volts d-c are required. The convection-cooled units are run at a conservatively higher-rated current density.

A slow, gradual aging (increase in forward resistance) is characteristic of all selenium rectifiers. Any slight effect this may have on output voltage can be readily offset by occasionally changing transformer taps. It is conservatively estimated that these power supplies will deliver their full rated output in normal elevator service for 15 years or more.

The units are rated at a normal ambient temperature of 35 C. Operation at higher temperatures is permitted by derating the output of each unit, and the requi d-c power obtained by installation of additional pacity. Only 4 percent ripple is obtained in the output of a 3-phase, full-wave bridge with a balanc 3-phase input; this assures continuous operation of d-c motor without overheating.

Operating Advantages

Economical operation is assured by the high e ciency of these units. Between 83 and 87 percent can expected for newly installed units. This efficiency c be maintained over an operating range of from o eighth to full load. Although this efficiency will decre somewhat with aging, it will not drop below a minim 78 percent.

The inherent voltage regulation of selenium rectifi is from 10 to 13 percent. This regulation, which further emphasized during the starting of the elevat when high peak currents occur, assures smooth eleva rides. When one power supply is being used for ea elevator, the regulation provides for smoother ope tion by softening the harshness of the rheostatic contr

In buildings where more than one elevator is use essential service can be maintained by the use of separate rectifier power source for each elevator. T running of two or more elevators from one pow supply is not recommended, since speed changes in o unit would be noticeable when any of the others sta Special arrangements can be made for applicatio where a number of elevators are used: the regulati is controlled and several rectifiers in parallel provi d-c power to the elevator motors.

The main operating advantages of selenium rectifi for d-c elevator drives can be summarized as follows

(1). *Low installation cost.* Selenium-rectifier un do not require special mounting platforms or found tions, but can be placed on any level surface. El tric connections are few and can be easily made.

(2). *Low operating cost.* Since the output pow of these rectifier units is controlled by the inp from the a-c transformer, little or no power is lo in heat. Consequently, the units have a high e ciency and low operating cost. With an elevator-ty load, a power factor of 95 percent or more leads power-bill economies.

(3). *Ease and simplicity of operation.* The un are operated by pressing the START or STOP butto

(4). *Low maintenance cost.* The equipment h no moving parts except a small fan in the larger un As with all static equipment, maintenance costs a at a minimum. The fan requires lubrication once twice a year.

(5). *Additional capacity.* The units are co servatively rated to give specified ratings on continuous-duty basis. Infrequent overloads (1 percent load current for periods up to one-half ho will cause no damage. Should additional capac be required at any time, the user can add units parallel and thus increase the capacity of the instal tion.

ical Application

pecial problems pertaining to elevator application perhaps be best studied by considering an actual blem:

twelve-story downtown office building is at present plied with d-c power at 250 volts. Several elevators, h powered by a 40-hp rheostatically controlled d-c tor, daily carry exacting passengers to the various er-story offices. In a building of this type, therefore, endable elevator service is essential. The power npany has informed the building management that it as to discontinue the d-c supply, and that in the ire only 460-volt 3-phase 60-cycle power will be ilable.

wo 20-kw selenium rectifiers and a dynamic-king protective panel provide the equipment neces- for the power-supply conversion of each elevator, llustrated by the diagram shown in Fig. 4. Three-se a-c power is supplied to each of the selenium-ifier units, whose outputs are connected in parallel rovide the correct d-c power to the elevator motor. ne special precaution should be borne in mind, ever. Many elevator-type loads are regenerative depend upon electric pumpback in their operation. the selenium rectifiers cannot absorb this excess er, a dynamic-braking protective panel and resistor required. The protective resistor is connected across line when pumpback occurs. For certain types of ator drives it is estimated that the value of the orbing resistor should be about 40 percent of the e of the power supply. For the problem considered , a 16-kw resistor should be sufficient.

henever regeneration occurs, the rise in voltage ates a voltage-sensitive relay, which in turn holds he load resistor contactor. Thus, the absorption stor is put across the line. A time-delay relay ases the contactor after a predetermined interval. he elevator load is still overhauling, the voltage-itive relay will again see a high line voltage, and the le cycle of operation will be repeated.

With all excess electrical pumpback energy safely absorbed by the protective resistor, the selenium rectifier is protected for reliable and continuous operation.

Summary

Every morning, noon, and night, elevators powered by selenium-rectifier conversion equipment provide essential and reliable service to thousands working and living in multi-storied buildings. Up to the present time, Chicago has installed capacity valued at approximately $250,000.

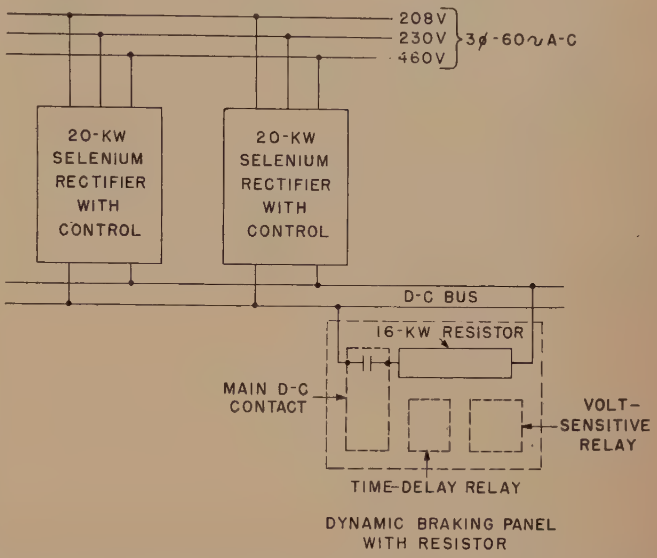

208V
230V
460V
3∅-60~A-C
20-KW SELENIUM RECTIFIER WITH CONTROL
20-KW SELENIUM RECTIFIER WITH CONTROL
D-C BUS
16-KW RESISTOR
MAIN D-C CONTACT
VOLT-SENSITIVE RELAY
TIME-DELAY RELAY
DYNAMIC BRAKING PANEL WITH RESISTOR

Fig. 4. Installation diagram showing two rectifiers connected in parallel and wired to a dynamic-braking panel. A protective resistor is connected across the d-c bus

The application for this equipment is steadily growing, not only in transporting people but also in moving freight. Wherever d-c power is required for old elevators, metallic-rectifier power supplies give a dependable, convenient, and economical solution to elevator power-supply problems.

LIGHTS AND SIDE LIGHTS

Rainmaking Trees

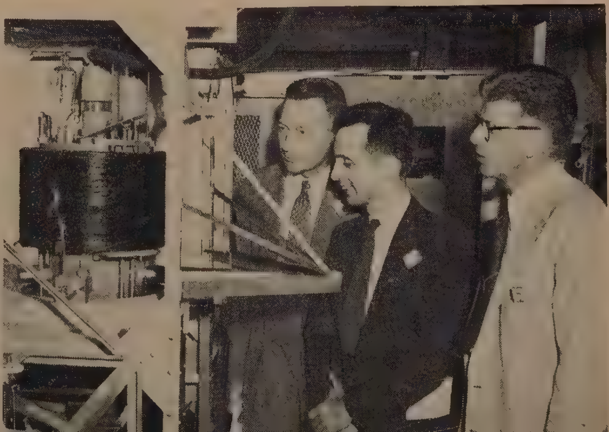
e mountain pine tree may prove to n excellent rainmaker by "needling" ture from passing clouds and fog.

cording to top weather scientists, the les of pine and other evergreen trees ing on mountainsides are good collec- of tiny water droplets in clouds and which collect them. Under certain itions, such collected moisture has observed to drip fast enough to give ppearance of rain.

ans are afoot to conduct detailed es of the amount of precipitation pro- d in this manner and ways in which it t be augmented by man. It is be- d possible that the use of specific of evergreen trees in reforestation of ered-off or burned-off mountain might have an added benefit in increased rainfall. It might also be possible to devise artificial structures with the same moisture-catching properties to enhance this source of water supply.

Tiny water droplets composing clouds apparently strike and stick to evergreen needles, then join and grow to raindrop size. In this manner, the evergreens can collect and shed water as long as the cloud moisture supply is available. Clouds should have a speed of five to ten miles per hour, which is common, for the rainmaking process to work efficiently.

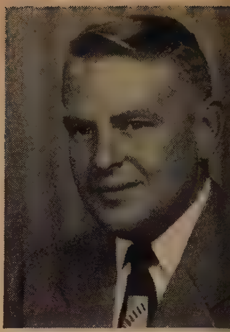
UHF Television



World's most powerful ultrahigh-frequency television transmitter is explained to visitors at Electronics Park, Syracuse, where tests of the equipment are now being made.

ELECTRIC EQUIPMENT FOR NEW MULTIPLE-UNIT CARS

Numerous improvements and innovations in design and construction give these suburban trains greater comfort and simplify their operation and maintenance



D. S. Onne

By D. S. ONNEN

Locomotive & Car Equipment Department
General Electric Company

SUBURBANITES in the Greater New York metropolitan area, traveling the Harmon-Grand Central Terminal and the White Plains-Grand Central Terminal electrified lines of the New York Central Railroad, are riding in new comfort. Trains composed entirely of new multiple-unit cars having many innovations are setting a new high standard in commuter service. The 100 new cars now in service operate from the existing 600-volt third-rail system, supplementing the 351 cars placed in operation between 1907 and 1930.

The new cars were built by the St. Louis Car Company; the electric propulsion and control equipment was manufactured by the General Electric Company. All cars are motorized, each one having two four-wheel trucks with 36-in. wheels and roller journal bearings. Each car weighs approximately 150,000 lb, without passengers, and is capable of seating 130 persons. The length over couplers is 85 ft, and the truck wheel base is eight feet. The car body is of lightweight, welded construction using high-tensile low-alloy steel.

Pleasing external contours, smart fittings, and picture-type windows mounted in aluminum frames, shown in FIG. 1, all contribute toward giving the cars a modern appearance, in harmony with designs already established for present-day mainline equipment. The interior, shown in FIG. 2, is painted in light-toned shades, and the moldings and other appointments are, in general, of aluminum and stainless steel. Continuous tubular, stainless-steel luggage racks are installed throughout the length of each car. Fluorescent lighti is used, with a continuous row of fixtures down t center line of the car ceiling. In keeping with t modern trend, each car is air-conditioned to furtl increase the comfort of the passengers in both summ and winter.

Trains are made up of from two to fifteen of the n cars. The control is set to provide an average accele tion of 1.5 mphps on a five-car train without passen load. Such a train could have a free-running speed, level tangent track, of 70 mph, when operating wit 600-volt power supply from the third rail; howev the railroad restricts multiple-unit car speeds to 60 m in its electrified territory.

Traction Motors

The traction-motor application is unusual for su urban coaches. It incorporates many improveme which constitute radical departures from previ multiple-unit practice. Four truck-frame-mounted s ventilated motors are installed on each car. Each mo develops 100 shp at the one-hour rating, when operat with 300 volts across its terminals. The motors insulated for a nominal operating potential of 600 v to ground, and the two motors on each truck permanently connected in series.

The traction equipment includes the motor its mounted on the truck transom, a flexible coupling afford positive drive between the motor and gear u

Fig. 1. Lightweight all-welded coaches, 85 ft long, with modern wide windows, carry multiple-unit undercar equipment

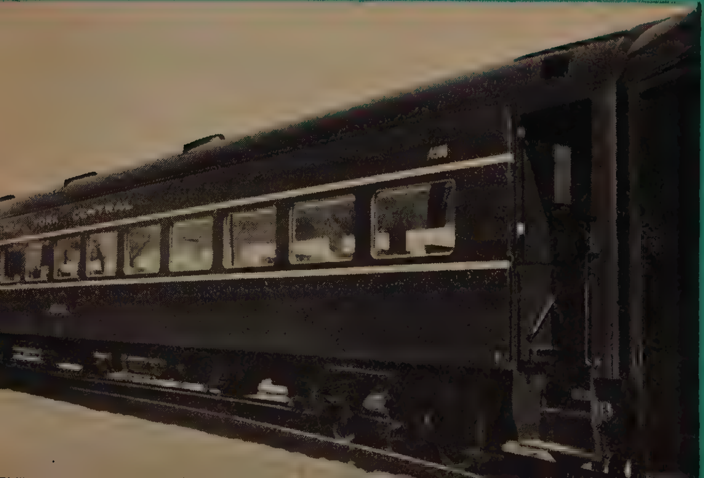
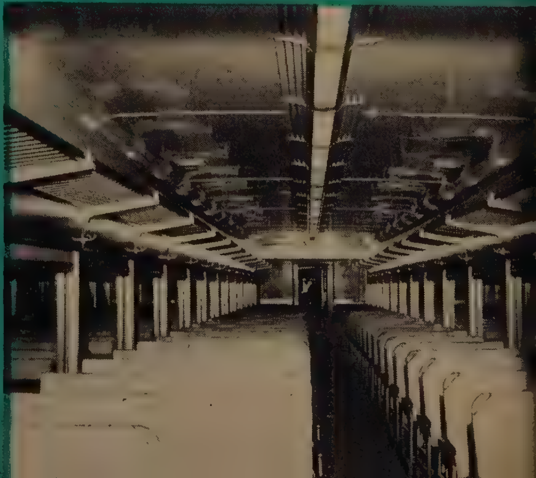


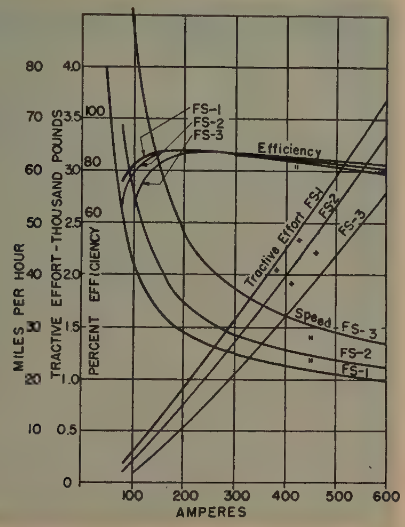
Fig. 2. Fluorescent lighting, continuous tubular luggage ra and a water cooler are new internal features. Additional sea capacity is provided by extra-wide seats on one side



a single-reduction gear unit complete with hanger mbly. One complete motor-gear unit equipment hs slightly less than 2400 lb.

he four-pole d-c commutating-pole motor used on e cars was designed especially for suburban service, a view to providing maximum capacity with mum weight. Performance characteristics of this or are shown in Fig. 3. The frame is of the rolled- e type, fabricated for lightness in weight. All top rs are provided with expanded metal to allow free low through the machine. The armature shaft is d, on the commutator end, with a ball bearing con- ed in a cartridge-type enclosure; and on the drive with a roller bearing. Grease lubrication is used onjunction with all-metal labyrinth seals.

rrangement of the car underside was simplified by use of self-ventilated motors. This eliminated the ssity for running numerous air ducts under the h from separate blowers to the traction motors.



. Diagram of perfor-
e characteristics of the

ventilating air is drawn in through protected ings in the upper commutator cover and distrib- in two paths. One air stream passes under the mutator and through the longitudinal ducts in the ature core; the other passes over the armature and nd the field coils. A fan expels the two streams of hrough openings in the frame.

he motor torque is transmitted to the wheels ugh a flexible coupling and rubber-supported gear- pinion assembly. The coupling is of the double nal-external gear type, which acts as a spline and nits vertical and horizontal misalignment. The rnal teeth on the coupling pinions are crowned, hat they can swivel freely in any direction with ect to the internal teeth on the sleeve, through an e equal to the maximum angular-misalignment city of the coupling. The coupling is grease- cated. Flexible synthetic-rubber seals, fitting ly around the pinion shafts of the motor-and-gear are provided to retain lubricant and exclude dirt. e fabricated-steel gear housing is supported on the by roller bearings. The pinion shaft is connected e flexible coupling at one end, and runs in two

Modern cars are air-conditioned for summer and winter comfort of suburban commuters on the New York Central Railroad

roller bearings that are mounted in the gear housing. The transom end of the housing is supported from the truck frame by a rubber-cushioned hanger. A ground brush is used to by-pass propulsion current around the roller journal bearings.

The gear-and-pinion mesh, as well as the bearings, are oil-lubricated by a combined splash and dip system.

Improvements in Operation

Many features incorporated in this equipment help overcome a number of problems associated with older types of multiple-unit car equipment. For example, the use of four motors per car eliminates all idle axles. Consequently the required accelerating tractive effort is obtained at a low value of adhesion, reducing the tendency to slip under unfavorable rail conditions. Distributing the motor weight over all axles, instead of concentrating it on two, gives a definite advantage. This, together with the use of truck-mounted instead of axle-hung motors, reduces the associated unsprung axle loading. As a result, road shocks are minimized, which means better riding qualities and reduced maintenance on motor and truck parts. The use of completely self-contained roller-bearing gear units with solid helical gearing minimizes noise and vibration. Oil lubrication of both gears and bearings insures quiet, dependable service.

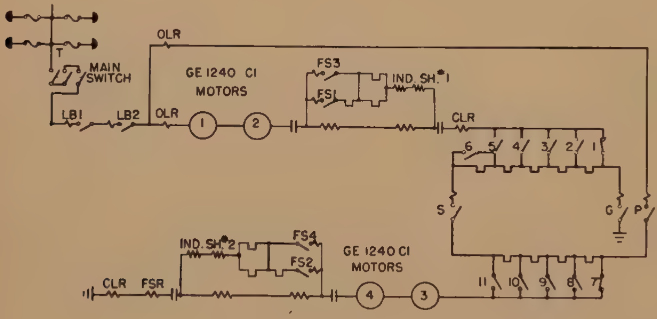
Control Equipment

The propulsion control equipment of the new cars includes two steps of field shunting. The traction motors are controlled by an electro-pneumatic mechanism, which operates a camshaft to positively open spring-closed resistor contactors. This method of commutating the accelerating resistance insures positive sequence without the use of elaborate mechanical or electrical interlocking schemes.

The electropneumatic controller on each car in a train is operated from the master controller in the engineer's cab of the leading car. To provide smooth acceleration, the four traction motors on each car are first connected in series and the resistance is cut out in

Trains of two to fifteen new multiple-unit cars, each driven by four truck-mounted motors, now operate on the 600-volt third-rail system

nine steps, as shown by the diagram and sequence table in Fig. 4. The progression of the electropneumatic controller from step to step is governed by an accelerating relay which holds constant current through the motors. The circuits are so arranged that, after transition from series to series-parallel motor connections, acceleration is continued by rotation of the controller camshaft, back through the nine steps to its original position. A notching relay enables the engineer to arrest the accelerating progression by moving the master-controller handle back one notch, a feature which has been incorporated to approximate the operation of controllers on the cars already in service.



SEQUENCE OF CONTACTOR CLOSING

STEP	PC POS.	LINE BRK. LB1	LB2	MOTOR CONTROLLER 1	2	3	4	5	6	7	8	9	10	11	CONTACTORS P	S	G	FS1&2	FS3&4
OFF	1			●						●									
1	1	●	●	●						●						●			
2	2	●	●	●					●	●						●			
3	3	●	●		●				●	●	●					●			
4	4	●	●		●	●			●		●					●			
5	5	●	●			●			●		●	●				●			
6	6	●	●			●	●		●			●				●			
7	7	●	●				●		●			●	●			●			
8	8	●	●				●	●	●				●			●			
9	9	●	●					●	●				●	●		●			
9A	10	●	●					●	●					●		●			
T	10	●	●					●	●					●	●	●	●		
10	10	●	●					●	●					●	●		●		
11	9	●	●					●	●				●	●	●		●		
12	8	●	●				●	●	●				●		●		●		
13	7	●	●				●		●			●	●		●		●		
14	6	●	●			●	●		●			●			●		●		
15	5	●	●			●			●		●	●			●		●		
16	4	●	●		●	●			●		●				●		●		
17	3	●	●		●				●	●	●				●		●		
18	2	●	●	●					●	●					●		●		
18A	1	●	●	●						●					●		●		
19	1	●	●	●						●					●		●	●	
20	1	●	●	●						●					●		●	●	●

Fig. 4. Connection diagram and chart of contactor sequence

Two steps of field shunting are provided when the motors are in the final running position—two in series, two groups in parallel. This gives a total of 20 steps, double the number on the older cars. After all accelerating resistance has been cut out of the circuit, the four field-shunting contactors automatically close, inserting suitable resistance and inductance in parallel with the main motor fields. The first step of field shunting is controlled by the accelerating relay, and the second by the field-shunting relay.

Master Controller

Engineers' compartments are located at diagonally opposite corners of each car, permitting use of the cars in any desired combination. The design of the ma controller in each compartment embodies many d able features that have already been tested on o modern equipments. It is of the cam-operated individ switch type, and is equipped with a safety-control up operating handle which acts to remove power apply emergency brakes if the pressure of the e neer's hand is released. The controller has five positi OFF, SWITCHING, SERIES, SERIES PARALLEL, and FI SHUNTING. By the use of a special reverse-handle l ing mechanism, one type of key will lock and un controllers on both new and old cars.

A pair of line breakers, working in conjunction the master controller, initially closes the traction-m circuit, and also acts to break the circuit when con power is removed. This device consists of two elec pneumatic contactors connected in series to af satisfactory line-current interrupting characteris It also serves to protect the traction motors aga overloads and power interruptions.

An unusual feature of these cars is the use c circuit-breaker as a main switch and the installa of circuit breakers in the control and lighting circ wherever possible.

The control includes a high-speed potential r which is energized as soon as the collector shoes con the third rail, and which is adjusted to drop out if line potential falls below a certain value. When relay contacts open, the main circuits are interrup and the motor controller automatically moves to OFF position. This prevents restoration of line poten on the motors until the full value of starting resista is in the circuit.

The control, lighting, and battery circuits are s plied by a 4-kw 600/75-volt d-c motor-generator which floats across a 48-cell battery rated 170 amp hours at the eight-hour discharge rate. The 600- motor of the set is connected to the line in series w one step of starting resistance, which is short-circu by a contactor when the voltage of the 75-volt ator reaches approximately 50 volts. The operat- oil of this contactor is in series with an auxiliary ock on the potential relay. This provides protec- in the event of a heavy reduction or complete uption of power, by insuring that the set can be nected to the line only with maximum resistance ies with the motor.

e air-brake equipment is a combination of auto- and electropneumatic passenger-car systems. It oys the D-22-BR control valve, which is the ard for interchange passenger cars, and includes opneumatic features for high-speed operation. The ic portion of the brake equipment consists of two et valves on each car, controlled by the engineer's valve on the head car. This arrangement insures taneous operation on all cars of a train. Air pres- s maintained by a 600-volt single-stage air com- or having a piston displacement of 35 cfm.

onditioning

nmer and winter comfort are afforded by the air- tioning system installed on the new cars. For summer operation, the unit is capable of providing seven tons refrigerating capacity on each car. The air-conditioning compressor is driven by a 13-hp 600-volt d-c motor, and the condenser and evaporator fans are each driven by a 1-hp 600-volt d-c motor. Air-conditioning control panels thermostatically control the rotating equipment. Compressor and condenser units are mounted under the car, while the evaporator, with its associated fan equipment, is located above the ceiling. The same fans are used to circulate the air at all seasons. In summer the air is cooled by the evaporator, and in winter it is heated by electric strip heaters mounted in the air duct between the ceiling and roof. This heating is supplemented by strip heaters located in protective housings around the sides of the car at floor level.

The numerous improvements and innovations in design and construction embodied in these cars place them among the best suburban equipment in operation today. Many thousands of commuters are benefiting daily from the increased comfort and convenience of the new trains.

Indoor-outdoor Current Transformers

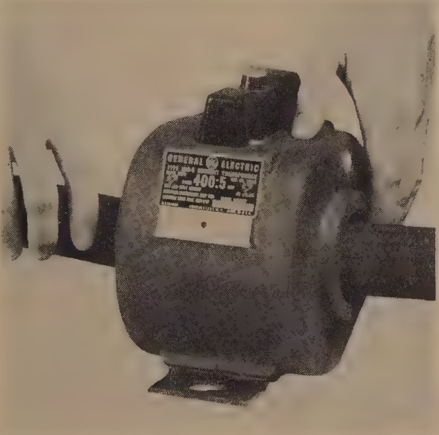
oduced two years ago for indoor t transformers, the butyl-molding s has now been applied to an entirely ne of current transformers, the first ped for both indoor and outdoor ation. The new line of 600-volt rmers can be used on single-phase n polyphase circuits. These butyl- d units were designed to reduce ers' stock requirements and help cut ory costs.

main problems associated with the butyl on outdoor transformers— penetration, sealing of butyl to parts, and surface creepage—had olved by two years of research and . The butyl insulation combines oisture absorption, good corona nlight resistance, excellent adhesion er, very low power factor, and good nce to mechanical damage. By the utyl, expensive porcelain and metal re eliminated, and the molded in- n permits compact designs meeting rd mounting dimensions for indoor tions, and is completely water- or outdoor service.

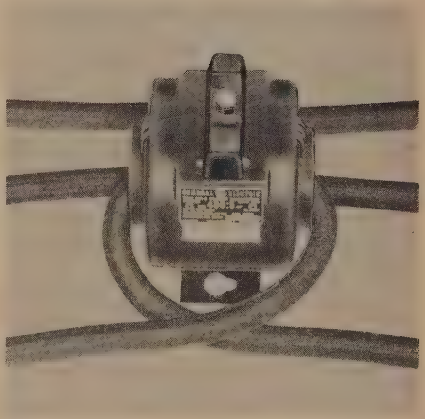
ors, the new transformers can be ed in any position, on any flat sur- hey are especially suited to use in oxes, because secondary terminals top and transformers can be mount- e together. Reversing the secondary llows metering leads to leave the rom either side. When used out- the butyl-molded transformers can alled on poles, without cross arms osing boxes.

of the new line is a 600-volt -type current transformer with primary ratings of 200-, 400-, and 600-amp—designed to carry continuously 200 percent of rated primary current. When mounted on an adapter plate, the new transformer meets dimensional requirements of EEI specification MS2 for low-voltage metering current transformers, thus increasing its interchangeability.

Butyl gum is a synthetic elastomer that has extremely good chemical stability and resistance to oxidation. To adapt the gum for transformer insulation, it is mixed with fillers, vulcanizing agents, and plasticizers.


The first indoor-outdoor butyl-molded transformer, 600-volt window type

Detailed experiments were performed to test the resistance of butyl to water penetration, weathering, and surface voltage creepage. No change in power factor occurred after 55 days immersion of a ⅛-in. layer of butyl in water of room temperature (25 C).

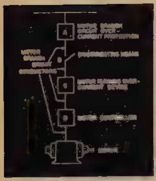

Two-inch window permits use as a three-wire transformer

Silicone-steel core, secondary winding, and base of the indoor-outdoor transformer before molding

APPLICATION OF AIR CIRCUIT BREAKERS IN A-C MOTOR CIRCUITS

Philip L Ca

In addition to branch-circuit protection, modern breakers can serve as the motor controller, the motor-running overcurrent protection, and the disconnecting means in a-c motor circuits of 600 volts or less



By PHILIP L. CAMP
Switchgear Department
General Electric Company

LOW-VOLTAGE air circuit breakers are frequently used for motor-branch circuit protection. Recent developments, however, make it possible for modern breakers to serve in other capacities as well. Therefore, it might be helpful to clarify the role played by the air circuit breaker in motor-branch circuits.

It is the purpose of this article to outline the possibilities of breakers as applied in motor-starting equipments. Particular emphasis is placed on recent developments of breakers for use as the motor controller.

Motor-circuit Requirements as Met by Breakers

FIG. 1 represents schematically the elements of a motor-branch circuit. The requirements of these elements and the extent to which they are met by circuit breakers are described:

Motor-branch-circuit Overcurrent Protection

The purpose of this device is to protect the branch-circuit conductors, the motor control, and the motor against overcurrents due to short circuits or grounds. Such protection requires that this device be capable of interrupting any short circuit at or beyond its load terminals. Because a circuit breaker is primarily a circuit interrupter, it serves this purpose admirably. Normally, a breaker used for motor-branch-circuit overcurrent protection is equipped with series overcurrent trips which give both time-delay and instantaneous short-circuit protection.

The time-delay-element pickup should be set low enough to trip on faults which would damage the branch-circuit elements. The time delay afforded should be sufficient to allow the motor to start without trip out as a result of the motor-starting current. National Electrical Code requires time-delay pi settings not greater than 150 to 250 percent of m full-load currents depending on the degree of m locked-rotor current.

The instantaneous trip pickup should be set c as close to the maximum motor inrush curren possible to allow for fast tripping on short circ Experience shows that an instantaneous element se of 150 percent of motor nameplate locked-rotor cu is the minimum permissible to ride over the c current in the highest phase during full-voltage star A setting of 200 percent is preferable.

Such time-delay and instantaneous pickup set are readily available on circuit breakers. Sufficient delay to allow for motor acceleration can be obta from either thermal-magnetic or dual-magnetic c current trips. Thus, in general, circuit breakers do nish all the requirements of motor-branch-circuit c current protection.

Disconnecting Means

The purpose of this device is to disconnect the m and controller from all ungrounded supply conduc A circuit breaker is a special type of switch; as s it is capable of performing the functions require the disconnecting means.

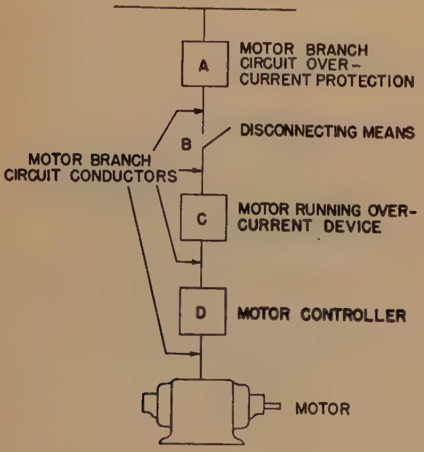

A
MOTOR BRANCH CIRCUIT OVER-CURRENT PROTECTION
B
DISCONNECTING MEANS
MOTOR BRANCH CIRCUIT CONDUCTORS
C
MOTOR RUNNING OVER-CURRENT DEVICE
D
MOTOR CONTROLLER
MOTOR

Fig. 1. Elements of a motor-branch circuit

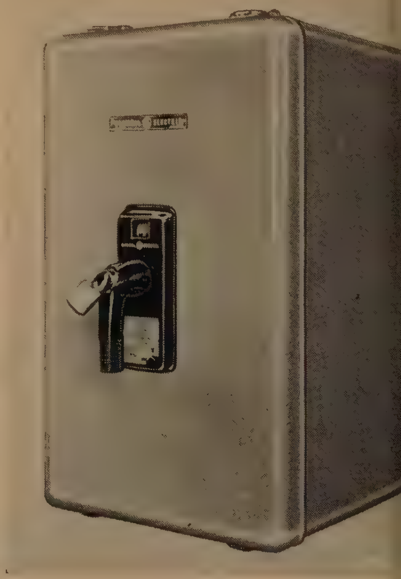


Fig. 2. Modern enclosed air circuit breaker with manual handle, mechanical indicator, electrical close push button, and with manual trip button padlocked in the trip-free position

Iodern circuit breakers are so equipped for menical indication of the breaker position that the rator is certain at all times whether the circuit ıker is open or closed. In addition, when these ıkers are of the draw-out or plug-in type, the withwal of a breaker from the connected position provides ırther indication, due to the presence of a visible break, that the motor circuit is disconnected from ungrounded supply conductors.

reakers are operable manually by a handle and y can be padlocked in the open (trip-free) position revent accidental closing during periods of maintece on the circuit. These features, as built into a lern circuit breaker, are shown in FIG. 2.

ircuit breakers have another advantage beyond furning all the necessary disconnecting functions in that y can be safely opened under load or overload, and y will clear under short-circuit conditions.

tor-running Overcurrent Protection

he function of this device is to protect the motor, trol, and branch-circuit conductors against overting due to motor overloads. Such protection rees that this device open the motor circuit if the rload persists long enough to cause excessive heating he circuit elements.

verloading may be caused by the addition of too ch driven load to the motor; by excessive mechanical tion, such as bearing failure; by single-phasing; or subnormal voltage. The National Electrical Code iires pickup settings of the overcurrent device at n 115 to 125 percent of motor full-load current for C motors and at 115 percent maximum for all other ors.

ime-delay elements of circuit-breaker series-overent tripping devices can be set at these values with icient time delay incorporated to allow for the eleration of the motor. This time delay is usually rt enough to take the motor off the line before exive heating occurs due to either moderate overloads ingle-phasing. Often, it is not short enough, howr, to protect the motor windings from overcurrents r stalled-rotor level. Circuit-breaker manufacturers faced with the problem of supplying series-overent trips with sufficient time delay to get motors ted and still protect those motors with short, safe, ting limits. There are broad variations in motorelerating time and in safe heating limits. Thus a e-delay characteristic which will permit starting of t motors often will not protect those with short heating limits.

IG. 3 shows a time-current characteristic of a series-current trip designed especially for motor-starting y. This characteristic is plotted as a band with imum and minimum tripping times shown. The d width represents all possible variations in time current due to manufacturing and testing toleres, as well as the effects of ambient-temperature ations from 10 C to 40 C.

It has been determined that a time delay of 15 sec at 6-times pickup will start the great majority of motors. This point fixes the minimum limit of the band. Manufacturing, test, and temperature tolerances require a band having an upper limit of 30 sec at the same current.

It is readily apparent that, if the particular motor being protected can safely withstand this current for more than 30 sec, the breaker alone will give adequate protection. Conversely, if the motor limitation is less than 30 sec, separate thermal relays must be used to give the necessary protection.

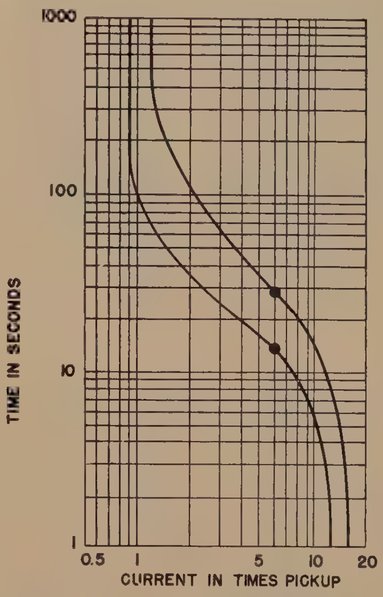


Fig. 3. Time-current characteristic of air circuit-breaker series-over-current tripping device suitable for motor-starting service

Because it has not been found practical to make a sufficient diversity of time-delay characteristics to meet all requirements, complete motor-running overload protection must usually be obtained by the use of separate thermal relays matched to the particular motor to be protected.

Motor Controller

The purpose of this device is to start and stop the motor. Such a device must be capable of making and breaking locked-rotor currents and should give a practical number of operations without contact maintenance for the duty on which it is applied. Most older breaker types were basically circuit interrupters with little or no emphasis given on their design for use as motor controllers. Their contact life at current levels of 5 to 6 times their continuous rating was rather short.

A breaker with a contact structure having adequate life when switching motor-starting currents was obviously very desirable. Such a breaker has been developed. FIG. 4 shows this breaker with an arc chute removed to show the contact design. The use of multiple contacts per phase tipped with silver tungsten carbide has proved far superior to older-type single-arcing con-

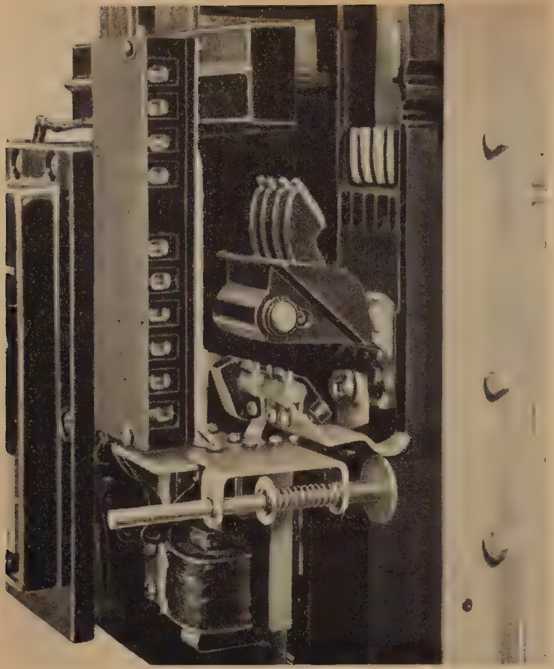


Fig. 4. Modern air circuit breaker suitable for motor-controller duty with right pole arc quencher removed to show multifinger silver-tungsten-carbide-tipped contacts

tact designs. These tests have shown this design to have an extraordinary long life on motor-starting duty; for example, the breaker shown will give 5000 operations making 4000 amp and breaking 600 amp without any contact maintenance. Life is, of course, much higher at lower current levels.

FIG. 5 indicates the life expectancy of breaker contacts on motor-starting duty for the most common ratings of this new multicontact air circuit breaker. After the number of operations listed for each of the two circuit breakers shown, their contacts were still in such condition that immediate replacement was not required but was indicated for the next maintenance period.

FIG. 6 is a schematic diagram of the test circuit used to obtain the data plotted in FIG. 5. The circuit is set so that with the shunting breaker closed, the test breaker is required to close against the inrush current. After a delay of 15 sec, the shunting breaker is opened, reducing the current to test-breaker continuous rating. The test breaker is then tripped. Such a test procedı adequately duplicates normal motor-starting con tions.

There are some applications where circuit break can not give adequate service. Contact life is not sat factory on highly repetitive starting duty. Pluggi and jogging can only be handled by a contactor. App cations requiring the repetitive opening of heavy lock rotor currents may give only about 10 percent of t life obtained on closing against such currents. Howev in applications where repetitive breaking of locke rotor currents is not involved, circuit breakers w generally give excellent service as motor controlle

Combining Motor-circuit Elements Into One Circuit Breal

Circuit breakers can therefore be used as mot branch circuit protection, as a disconnecting device, a motor controller, and in combination with separ thermal relays as motor-running overcurrent prot tion.

The features required for the first three motor-bran circuit elements can all be incorporated into c breaker. Separate thermal relays for tripping this sa breaker will provide the fourth. For many applicatio this single breaker can be expected to perform as complete motor starter with a maximum of reliabil and protection, at minimum cost.

Manual vs. Electrical Operation

Because proper closing speed is always obtained w electrically operated breakers, electrical operation recommended for motor-starting breakers.

Although manually operated breakers can be used motor starters, the speed of closing is usually depend on the operator; thus there is always the possibility improper closing. Breakers should be closed with c firm stroke—nudging or "kissing" of the contacts w result in their certain rapid deterioration.

Undervoltage Protection

A circuit breaker is a latched-in device which rema closed on loss of voltage. It is therefore recommenc that a motor-starting breaker be equipped with und voltage release. In addition, where separate therı relays are used, the relay contacts can be used to op

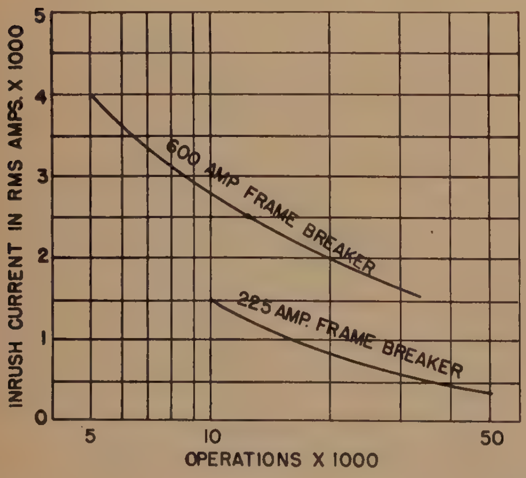


Fig. 5. Average expected operations closing inrush currents and opening rated current without contact maintenance for two modern 600-volt air circuit breakers

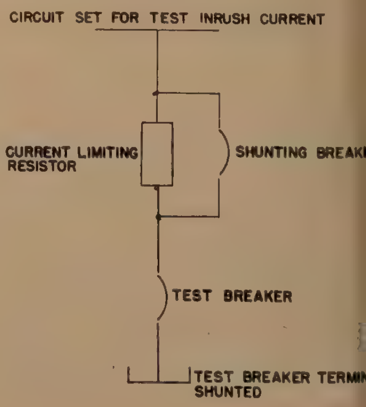
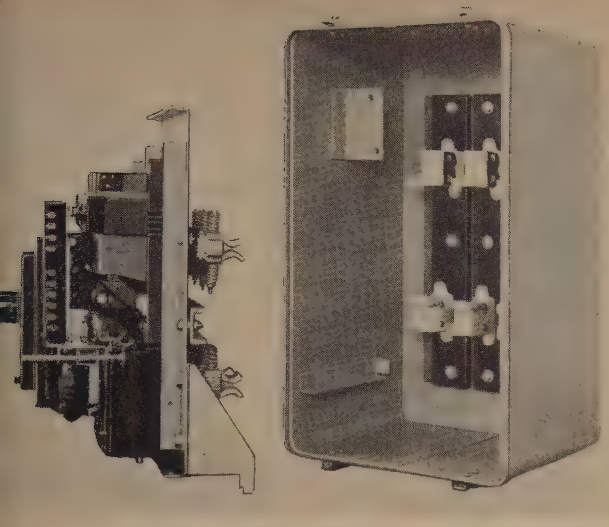

CIRCUIT SET FOR TEST INRUSH CURRENT
CURRENT LIMITING RESISTOR
SHUNTING BREAK
TEST BREAKER
TEST BREAKER TERMI
SHUNTED

Fig. 6. Test circuit for proving ability of breaker to make inrush currents and open rated current



. 7. Modern air circuit breaker suitable for motor-branch circuit plication removed from enclosure to show plug-in feature which allows removal for servicing and positive disconnecting

undervoltage-device coil, insuring positive tripping hout the necessity of having a reliable source of ping voltage.

ly Removable Breakers

reakers used as motor starters usually require more ntenance than ordinary feeder breakers because of more frequent operation. Draw-out breakers or plug-reakers as shown in Fig. 7, make this maintenance r and easier.

The feature of easy removability also permits maximum possible safety for personnel working on the motor or motor circuit. Complete removal of the breaker precludes the slightest possibility of energizing the circuit by mistake.

Motor-running Overcurrent Protection without Thermal Relays

Sometimes the breaker-tripping characteristic will match the safe heating characteristic of the protected motor, thus giving both sufficient time to start and adequate protection for all values of overcurrent. In such cases, separate thermal relays can be omitted.

Where continuity of service is essential, such as on central station auxiliaries, breakers are sometimes used as motor starters with instantaneous short-circuit trips only. Frequently, thermal or long-time-delay relays or even the series overcurrent-trip time-delay element can be arranged to sound an alarm rather than trip the breaker. Thus, faults are cleared by the instantaneous element, but the responsibility for shutting down overloaded motors rests with the operator.

References

NBFU Pamphlet No. 70, *National Electrical Code.*

"Thermal Co-ordination of Motors, Control and Their Branch Circuits on Power Supplies of 600 Volts and Less," by B. W. Jones, *AIEE Transactions*, vol. 61, 1942, p. 483.

"An Improved Design of Low-voltage Panel-mounted Air Circuit Breaker," by L. H. Sperow and J. A. Favre, *AIEE Transactions*, vol. 67, 1948, p. 695.

LIGHTS AND SIDE LIGHTS

"Shining Rails"

ining Rails, a new full-color 20-minute on picture on railroading, depicting part electricity plays in modern rails and portraying railroading progress ng the past 25 years, is now being n by the General Electric Company.

his dramatic 16-mm sound produc- filmed on locations from California ew Jersey, tells the story of major lopments contributing toward the ort, speed, and safety of passenger l, and toward improved service for nt movement.

ining Rails was produced by Academy uctions, Inc., of Hollywood for Gen- Electric. The Company's transporta- division supervised the production nically. It was directed by Richard rd, director of a recent prize-winning "The Titan."

oduced as an educational program to the public advances in modern rail- ng practices, the movie will be avail- or loan at General Electric Apparatus offices throughout the country. It can urchased at cost by organizations ng film prints for permanent use.

ning Rails is a sequel to *Railroadin'*, iced in 1940, which met with high c acclaim.

Mechanized Diagnosis of Diabetes

Precise determination of blood sugar content within limits of a diagnostic range in less than five minutes is now possible with a new machine which has been used to make tests on 4300 blood specimens in approximately 40 hours. Without the machine, processing this number of specimens would require 10 to 15 weeks of a laboratory technician's time.

Designed to provide closely controlled heating of the test tubes at various stations of the process is a Calrod* tubular heater, specially formed.

Special tablets of zinc hydroxide, potassium iodide, potassium ferricyanide, and tartaric acid are added to the specimen at various stations of the process. The test tubes are progressively heated, steamed, and subjected to subdued heat of the Calrod unit; then they are tilted, shaken, and cooled.

If the blood sugar value is below the screening level, the solution will be blue. If above this level, indicating an increase of blood sugar above the standard range, the solution will be colorless. This affords a precise, easy reading by the unassisted and untrained eye.

The machine is portable, weighing only 53 pounds. The Calrod heating element is protected by a guard. A reflector slide provides heat adjustment in case current drops below the normal 110 volts.

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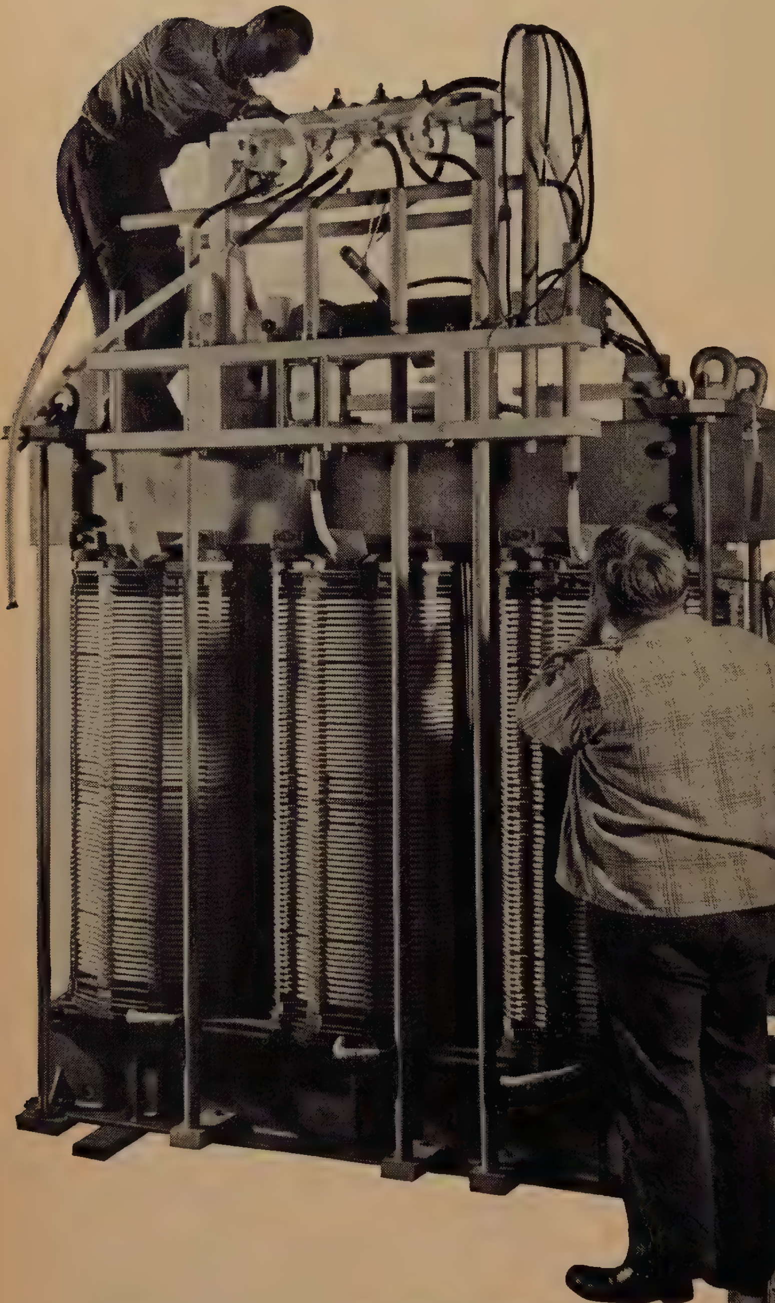

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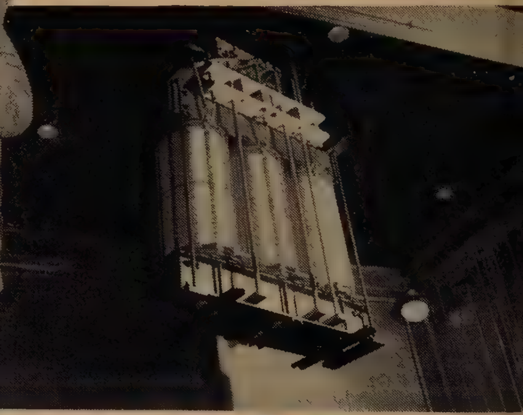

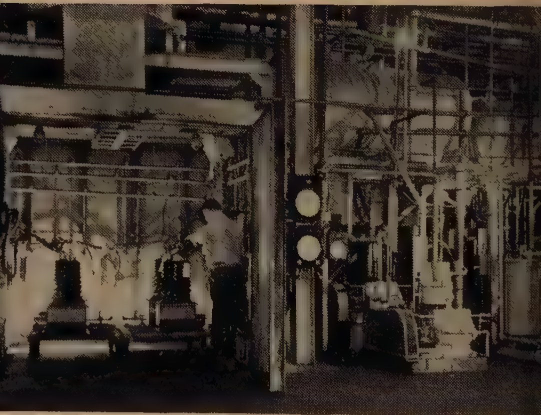

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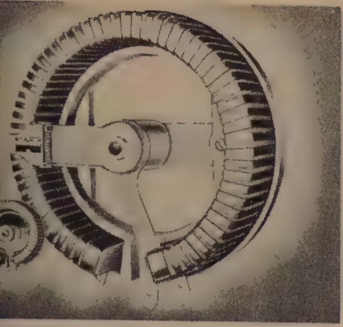
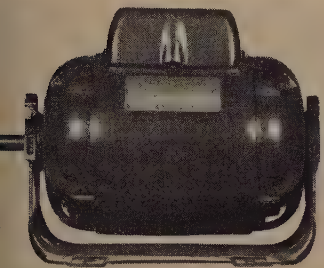
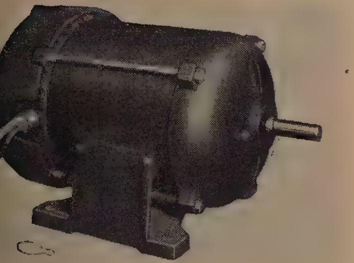


Rheostats

A line of vitreous-enamel power rheostats formerly manufactured by the Rex Rheostat Co. is being placed in production. They will be available in seven sizes, ranging from 50 to 500 watts. Interchangeable with the vitreous-enamel power rheostats produced by the industry, these however have a hinged contact arm which insures long life and freedom from excessive burn outs.—*P. O. Mallory & Co., Inc., Resistor Div., 3029 E. Washington St., Indianapolis 6, Ind.*



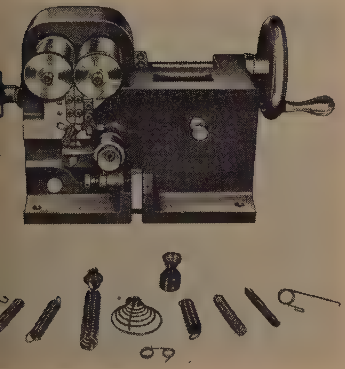


Capacitor Motors

The line of Tri-Clad* single-phase capacitor induction motors is now being offered with a resilient-base construction on motors rated from ½ to 5 hp, for use where freedom from vibration and extra-quiet operation are required. All single-phase motors have some torque pulsation, but the resilient base isolates this vibration so that it is not transmitted to the driven machine.

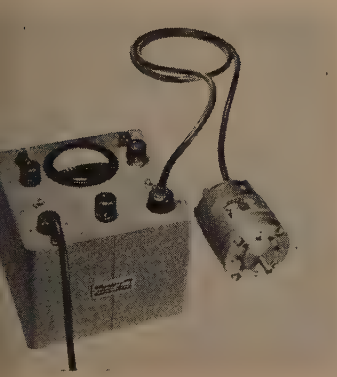
Another extension to this line is a motor of totally enclosed fan-cooled construction. Features include starting capacitors and a switch mounted within the frame to provide maximum protection with minimum space requirements. Available in ratings of 1, 1½, 2, 3, and 5 hp, the new motor was designed for use where extra severe conditions of dirt, grit, or moisture are encountered. It is also offered in explosion-proof and dust-explosion-proof construction for installation in hazardous locations. Typical applications are: coal stokers, exhaust fans, grain elevators, and fuel pumps.—*General Electric Company, Small & Medium Motor Divs., Schenectady, New York.*

*Reg. trade-mark of the General Electric Co.



Precision Spring Coiler

A spring coiler for making torsion, compression, extension, and tapered springs, coiled either right- or left-hand with no changing of arbors. The coiler will handle wire stock from 0.005 to 0.125. Springs can be made with or without initial tension and with open or closed ends. When individual or small groups of springs are needed for replacements or prototypes or experimental work they can be made in a matter of minutes, eliminating special orders and costly delays. The machine comes complete with 3 wire guides, 3 wire feed rolls, and 2 coiling points.—*Perkins Machine and Gear Co., Circuit Ave., West Springfield, Mass.*



Motor Control

A motor control, Type 301-A, consisting of a special motor and a companion control box. The combination provides finger-tip control of motor speed from 50 to 5000 rpm; between these speeds, the motor will deliver up to 10 in.-oz of torque. The action of the control is to maintain the speed approximately constant at the setting determined by the control knob, regardless of variations in the load-demand torque. In the laboratory, the control can be used to drive segmented disks, synchronous

(Continued on following page)

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Resistors and Rheostats

A complete line of wire-wound resistors and rheostats that meet requirements of joint Army-Navy specifications. The rheostats are offered in 11 types; they include both standard and enclosed types, in sizes ranging from 25 to 750 watts. They meet JAN-R-22 tests including: 5-hr vibration test; 50-hr salt-spray corrosion test; and 150-hr 95 percent humidity electrolysis test. The 33 styles of resistors offered represent five types, as follows: tab terminal; tab terminal with hole to clear No. 8 screw; ferrule terminal; flat-type tab terminal; and axial terminal. Each of the types is available in a complete range of sizes, wattages, and resistance values. These meet the JAN-R-26A tests including the 5-hr vibration tests and air-and-water tests for thermal shock.—*Ohmite Manufacturing Co., 4981 Flournoy Street, Chicago 44, Illinois.*

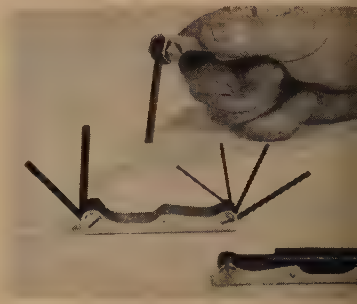
Tubes

Two tubes have recently been developed. One, a twin triode Type GL-5844, is expected to be widely used in "flip-flop" service in binary-system calculators. This tube replaces Type 6J6 and requires one-third less heater power than the former tube. The cutoff voltage between triodes balances within a one-volt limit. The second tube is a high-vacuum rectifier type, GL-5973, designed for use in radar both as a charging diode and as a limiter to restrict surge currents. Use of a thoriated-tungsten filament combined with a low voltage drop allow an average current rating much higher than that of other tubes of this class.—*Tube Divisions, General Electric Company, Schenectady 5, New York.*

Lamp Conversion Kit

Improv-a-Lite conversion kit for converting ordinary lamps to 3-way lamps in a matter of minutes. The kit, designed primarily for use with G-E white indirect 3-Lite bulbs, consists of a factory-wired 3-way socket, wide harp, 8-ft extension cord, and a clamp-on plug. Old-style lamps are quickly changed to the modern 3-way type, by removing the old wire, screwing on the Improv-a-Lite fixture, and clamping on the plug. The socket and plug are of ivory Beetle plastic, designed for attracti pearance and long wear. The use of plastic reduces the possibility of el shorts, and it will not dent, tarnish, apart.—*Monowatt, Inc., Providence, Island.*

Hand Tool



A single hand tool called the Smit that fits the small-size standard s head screws and bolts. A smaller copy Smitty 5-in-1 hand tool, the new devi six individual socket wrenches, sizes $\frac{1}{16}$ in., $\frac{5}{64}$ in., $\frac{3}{32}$ in., $\frac{1}{8}$ in., and $\frac{5}{32}$ in fold knife-like into a single sturdy h It is small enough to fit into a pock designed to permit needed leverage at angle.

When wrench ends become worn can be reground. Then, when com worn down, the individual wrenches easily replaced by removing the en and inserting a new wrench of the size.—*H. D. Hunter Co., 3499 E. 14 Los Angeles 23, California.*

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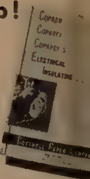

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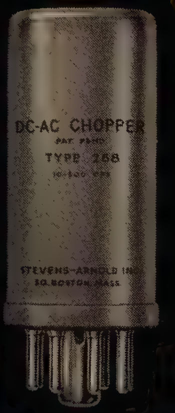

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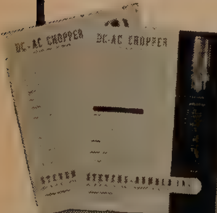

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Analog Computors—A catalog and manual on GAP/R High-speed All-electronic analog computors covering origin, development, applications, component philosophy, operating procedures, oscilloscope presentation techniques, choice of scale factors, etc. Thirty-six pages.—*George A. Philbrick Researches, Inc., 230 Congress St., Boston 10, Mass.*

Conduit and Cable Fittings—Listed in complete easy-to-find form are conduit and cable fittings for all types of raceways, grouped according to the raceway each serves. Large-size illustrations and the many charts of connector sizes and capacities, strain-relief bushings, and ground fittings make for easy selection. 68 pages. Bulletin No. 65.—*Thomas & Betts Co., Inc., Butler St., Elizabeth, New Jersey.*

Electronics—Explains the part electronics will play in America's defense economy, and General Electric's contributions to this period. Titled "Electronics in the Public Interest." Eight pages.—*Electronics Department, General Electric Co., Electronics Park, Syracuse, New York.*

Induction Heating—A bulletin containing a selector chart for induction heating and melting and a table giving heating and melting speeds for induction equipments, as well as case-history descriptions of actual installations. Eight pages. Bulletin No. 27A.—*Ajax Electrothermic Corp., Trenton 5, New Jersey.*

Microscopes—A line of laboratory scopes, called Dynoptic Labroscope completely described and handsomel trated. There is a section on optical ment for these instruments, and a list is included. Twenty-four pages. C D-185.—*Bausch & Lomb Optical Rochester 2, New York.*

Punch and Die Setting—A man practical information regarding th plication of the Cerromatrix meth making various types of dies. Pro illustrated with photographs and dra Twenty pages. Bulletin A15.—*Cer Pasco Corp., 40 Wall St., New York 5,*

Solder—An educational brochure o nature, properties, and uses of Following a list of practical applic and a comprehensive description Federated solders there is a résu specifications and technical data. T six pages. Titled "Solder."—*Fe Metals Div., American Smelting an fining Co., 120 Broadway, New York,*

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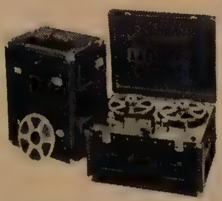

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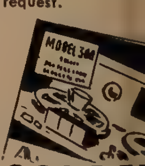

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BOOK REVIEWS

(Available books may be purchased through the GENERAL ELECTRIC REVIEW *for domestic delivery; none sent on approval.)*

TICIZERS
. Buttrey—Cleaver-Hume Press, Lon-
(New York: Interscience Publishers).
175 pp. $3.50.

is is primarily a compilation of data
manufacturers' trade publications and
British and American patents. It is
l to have this information in one place.
erous graphs and tables of properties
lso welcome. However, the book seems
essly written, a fault which seriously
s its readability. Some compounds are
operly classified. A fuller use of out-
style, in listing properties and uses,
d help. The last chapter does not give
coherent, lucid explanation of plastic-
action which is needed.

M. M. SPRUNG

ATOMS—PROGRESS AND SOME MEM-
S

Hahn (Edited by W. Gaade)—
ier Publishing Co., New York. 1950.
p. $1.75.

e personal reminiscences of a pioneer
ew field of science are usually of value.
his reason *New Atoms*, which is largely
ccount of Prof. Otto Hahn's important
in radiochemistry, will interest the
alist as well as the scientific layman, for
n it was intended.

e short book begins with the address
delivered on receiving the 1944 Nobel
in Chemistry. There follows an ac-
t of nuclear structure and an explanation of the chain reaction of uranium, a development which mushroomed from the 1938 observation of uranium fission in Hahn's Berlin laboratory. Next comes a review of the published information about the new artificial elements: technetium (43), prometheum (61), astatine (85), francium (87), neptunium (93), plutonium (94), americium (95), curium (96), berkelium (97), and californium (98). The final chapter is devoted entirely to Hahn's personal reminiscences, particularly of the halcyon period before World War I.

The book does not conceal the apprehension with which Hahn, a man recognized outside of Germany for his personal integrity, views the nucleus, from which vast energy is available for creation or destruction.

HERBERT C. POLLOCK

SURVEY OF MODERN ELECTRONICS

Paul G. Andres—John Wiley & Sons, New York. 1950. 522 pp. $5.75.

This book covers briefly the fundamentals of the operating principles of the majority of electron tubes available today. These include gas- and vapor-filled tubes such as neon and fluorescent lamps, Geiger counters, flash tubes, thyratrons, and ignitrons, the common high-vacuum tubes and special-purpose types such as magnetrons, x-ray tubes, cyclotrons and betatrons, photo-sensitive tubes and cathode-ray tubes. The construction of various tube types is illustrated by photographs and cross-sectional drawings. Interesting examples are given of their use in the fields of industrial control, instrumentation, communication, and entertainment.

The book is suitable for use either as a reference or as a textbook. Specific references and pertinent problems are located at the end of each chapter. An appendix contains a bibliography of general references, periodicals, and suppliers of education films dealing with electronics.

H. W. LORD

THEORY AND APPLICATION OF ELECTRICAL ENGINEERING

Eugene W. Schilling—International Textbook Co., Scranton (Pa.). 1951. 402 pp. $6.50.

Most college professors have individual ideas on how an engineering course should be presented; and they generally find it necessary to write a book in order to have an appropriate text for their particular course. Apparently this need prompted Mr. Schilling to write this book.

A wealth of electrical-engineering theory is presented, along with appropriate problems. The major emphasis is on basic circuit and machine theory, although one chapter on electronics and one chapter on illumination are included.

The chief emphasis of the book is placed on the presentation of a good physical picture to the student. Certainly the large

(Continued on following page)

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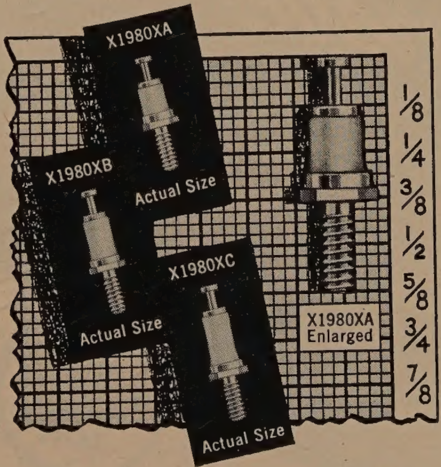

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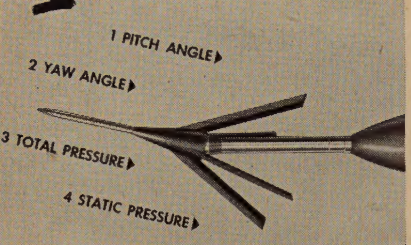

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BOOK REVIEWS (Continued)

amount of descriptive material does offer a logical persuasive presentation of the subject. Aside from its purpose as an undergraduate text book, the text may serve for the graduate mechanical engineer who would like to obtain an understanding of electrical-engineering phenomena through individual study. W. D. Bartlett

Quakers in Science and Industry

Arthur Raistrick—Philosophical Library, New York. 1950. 361 pp. $6.00.

Despite restrictions and persecutions falling upon them in the 16th and 17th centuries, the Quakers, through their unity, managed nevertheless to establish themselves in the growing industry, trade, and finance of England. Through all this, in the early years of the Society of Friends, they maintained strict adherence to their rules of simple living and freedom from luxury.

Quakers in Science and Industry presents a picture of the various activities open to the Quakers in these early days, and describes in interesting detail the growth of some of the more important company and family groups which eventually came to take a prominent place in England's commerce and industry. Roger C. Staples

Operational Calculus

Balth. van der Pol and H. Bremmer—Cambridge University Press, New York. 1950. 415 pp. $10.00.

Another extensive and comprehensive treatise on modern operational calculus is offered by one of the leading contributors to the subject. This really delightful book combines simplicity of presentation with vigor in demonstration and excels in a great variety of application to mathema physics, and engineering.

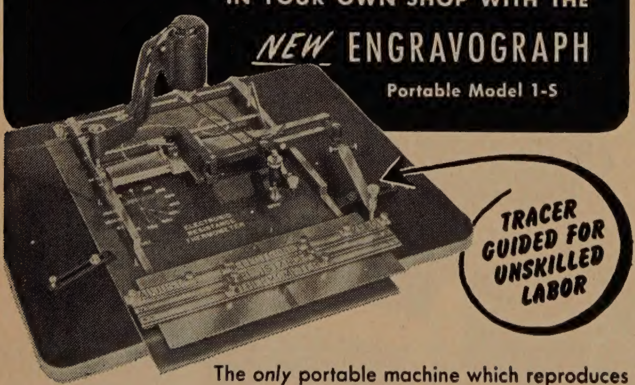
The operational rules are greatly sin fied by the use of the two-sided Lap integral, at the same time making a n larger class of functions and phy phenomena available for analysis. Althc a rigorous mathematical basis is establis proofs of the more advanced theorems l been left out to limit the size of the b The last chapter presents the theory simultaneous operational calculus, dea with the transformations of function more than one variable by means of mult Laplace integrals. The book closes witl extensive list of operational rules relations. G. K

Foundations of Aerodynamics

A. M. Kuethe and J. D. Schetzer—J Wiley & Sons, New York. 1950. 374 $5.75.

This is an excellent perspective surve aerodynamics. The number of topics which the authors have succeeded in viding introductions is remarkable. Som the topics, the treatment of isotropic anisotropic turbulence for instance, covered in a manner which is other available only in the original papers. In cases the problems are treated with s cient mathematical rigor so that t actually do provide a real introductio more advanced treatises on the indivic topics.

The use of vector analysis and of methods of advanced calculus is extens The book seems likely to be more use however, as a reference text to supplen some previous acquaintance with the s ject than as an introductory text. D. C. Prince,



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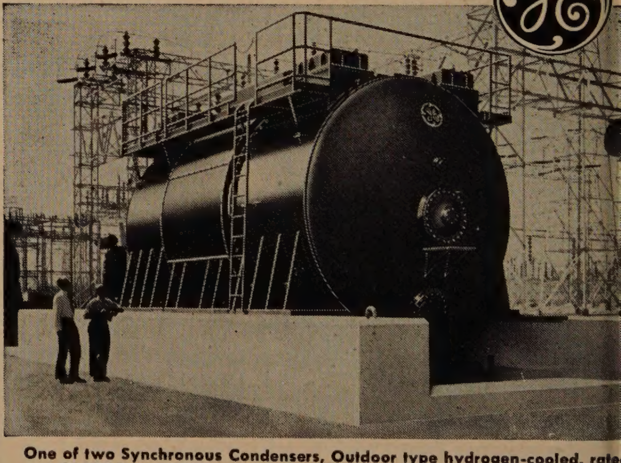

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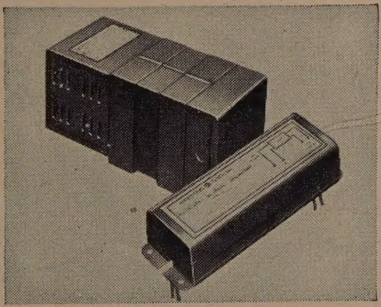

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ON ARTICLES IN OTHER TECHNICAL JOURNALS

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KIDDE'S ELECTRONIC FIRE DETECTOR. *Aviation Week*, May 14, 1951; v. 54, p. 50.

Describes a fire detector for aircraft engines.

PACKAGING OF AIR-BORNE ELECTRONIC EQUIPMENT. Orville M. Dunning. *Aero Engng. Rev.*, May, 1951; v. 10, p. 29.

The problems involved in assembling miniature electronic units for aircraft.

CALCULATING INSTRUMENTS

MECHANIZED REASONING; LOGICAL COMPUTERS AND THEIR DESIGN, by D. M. McCallum and J. B. Smith. *Electronic Engng.*, Apr. 1951; v. 23, p. 126.

Description of the Ferranti logical computer for the solution of logical problems of relatively simple mechanical means.

PRINCIPLE AND DESIGN OF A NEW TYPE STIELTJES INTEGRATOR, by Ernst H. Winkler. *Rev. of Sci. Instr.*, June 1951; v. 22, p. 406.

Describes a mechanical instrument for solving Stieltjes integrals.

GRINDING AND POLISHING

PRODUCTION PLUNGE-CUT GRINDING. Frank W. Curtis. *Tool Engr.* May, 1951; v. 26, p. 28.

Describes a type of grinding done by feeding an abrasive wheel directly into a cylindrical part, so that the entire width of the area or areas to be ground are finished simultaneously.

CORRECT MOUNTING METHODS ELIMINATE GRINDING-WHEEL BREAKAGE. *Steel*, May 7, 1951; v. 128, p. 122.

Information based on research on the amount of torque to use when mounting wheels on cylindrical grinding machines.

HYDRAULIC TRANSMISSION

CONSTANT SPEED FOR AIRBORNE GENERATORS, by George L. Christian. *Aviation Week*, June 25, 1951; v. 54, p. 48.

Describes Sundstrand's jet-engine-driven, hydraulic, constant-speed alternator drive.

HYDRAULIC SERVOCONTROLS IN THE STEEL INDUSTRY, by H. Ziebolz. *Instruments*, June 1951; v. 24, p. 650.

Advantages and disadvantages of hydraulic servosystems are explained and a method for obtaining proportional-plus-reset control with a hydraulic system is shown.

METALS

NEW MAGNETIC PARTICLE-TESTING TECHNIQUE SPEEDS INSPECTION OF FERROUS PARTS, by S. G. Kelley, Jr. *Mat. & Methods*, June 1951; v. 33, p. 66.

Modified magnetic particle-inspection method detects, in one operation, surface defects occurring in any direction.

POSSIBILITIES AND LIMITATIONS OF
MARFORM PROCESS. Henry P. Hessl
others. *Mach.*, May 1951; v. 57, p. 15

Gives specific information on the
cation and economical use of the p
in the manufacture of sheet-metal

RADIO ENGINEERING

AIR-TO-AIR TROPOSPHERIC RADIO P
GATION. G. B. Fanning and others.
Data Digest, May 1951; v. 16, p. 19.

Describes tests between two aircr
the same altitude over the same te

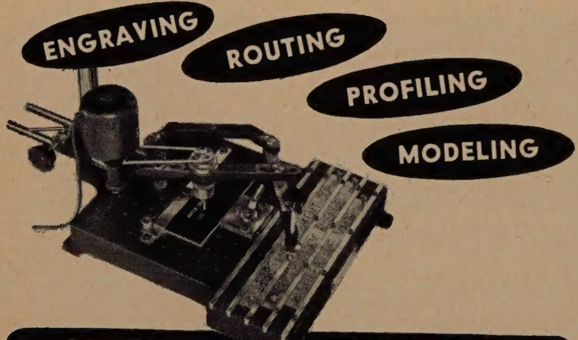
TRANSFORMERS

ELECTROSTATIC DIRECT-CURRENT T
FORMER OF 300 KILOVOLTS, by José M
Malpica. *Rev. of Sci. Instr.*, June 19
22, p. 364.

Describes an electrostatic transfor
direct current which permits the c
uous transfer of electrical charges f
primary circuit to a secondary circ
means of a rotating dielectric.

FORCED-COOLED TRANSFORMER COST
MIZED WITH OPTIMUM SECONDARY VO
RATING, by W. R. Bullard. *Elec. Lt.* &
July 1951; v. 29, p. 66.

Calculations make possible selecti
transformer secondary voltage
which will allow full utilization of r
ting equipment without exceeding
excitation limit of transformer.



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